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XX international scientific conference

World science priorities

Vienna
05-06.02.2026

World science priorities

Proceedings of the XX International Scientific and Practical Conference

5-6 February 2026

Vienna. Austria

2026

UDC 001.1

BBC 1

XX International Scientific and Practical Conference « World science priorities», February 5-6, 2026, Vienna. Austria. 122 p.

ISBN 978-92-44514-88-7

DOI https://doi.org/10.5281/zenodo.18613249

Publisher**: «World of Conferences»**

Main organization: **ESD GROUP**

Editor: Tarmo Vesik

Layout: Asko Laar

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The sample of the citation for publication is*: Farid Ibrahimov CONCEPT OF "SMART CITY" WORLD EXPERIENCE AND PLANS OF AZERBAIJAN // XX International Scientific and Practical Conference «World science priorities», February 5-6, 2026, Vienna. Austria Pp.15-17. URL: https://conference-w.com/*

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Arts

THE ARTISTIC AND PEDAGOGICAL CONTRIBUTION OF YEVHEN HUNKO AND VOLODYMYR SEMCHYSHYN TO THE DEVELOPMENT OF REGIONAL CHORAL ART IN UKRAINE

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Abstract

The choral traditions of the Ternopil region (Western region of Ukraine) at the turn of the twentieth and twenty-first centuries were significantly shaped by Yevhen Hunko and Volodymyr Semchyshyn, leading conductors and long-time lecturers of Ternopil National Pedagogical University. Through their artistic and pedagogical work, they strengthened both academic and community-based choral practice, contributing to the preservation and continuity of regional musical heritage. The article provides an overview of their work as pedagogues, conductors, and arrangers, outlining the main vectors of their professional activity.

Keywords: Yevhen Hunko; Volodymyr Semchyshyn; Ternopil; choral traditions; regional musical heritage; conducting pedagogy; choral arrangement.

Introduction.

Choral art has long occupied a distinguished place in the cultural history of the Ternopil region (Western region of Ukraine) . For centuries, this territory has fostered rich singing traditions, in which sacred, folk, and academic musical practices have coexisted and interacted within the everyday cultural life of local communities. The late twentieth and early twenty-first centuries, however, mark a particularly dynamic period in the development of regional choral performance. These decades were shaped by profound socio-cultural transformations and the emergence of a renewed national identity in independent Ukraine.

Within this context, the present study examines the artistic and pedagogical work of two influential choral conductors — Yevhen Hunko and Volodymyr Semchyshyn. Their professional activity not only contributed to the establishment and growth of a distinctive regional choral school, but also played a formative role in training new generations of choir directors and shaping the cultural landscape of the Ternopil region.

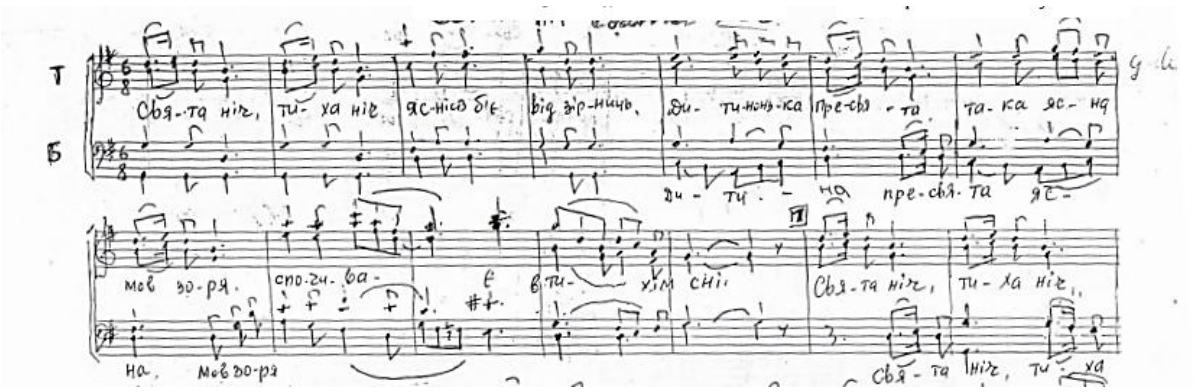
Artistic Activity of Yevhen Hunko

Yevhen Hunko, Honored Artist of Ukraine and associate professor of the Faculty of Arts at Ternopil National Pedagogical University, played a decisive role in shaping a distinct model of professional choral performance in the region. Over the course of several decades, he directed a number of university-based ensembles, including the women's choir, the choral capella «Osvita», and the renowned male vocal quartet «Acord», which he founded from among the most talented students (Kaniuka, A., & Protsiv, L., 2018). Under his leadership, these ensembles developed an exemplary academic choral sound: timbrally balanced, precise in intonation, and expressive in phrasing.

A defining aspect of Hunko's artistic legacy is his work as an arranger. His choral arrangements are marked by a rich harmonic vocabulary, linear independence of voice parts, and finely crafted texture (see Pic. 1).

These works require a high level of vocal preparation and ensemble coordination, and are therefore primarily performed by academic and professional choirs — a testament to Hunko's orientation toward elevated performance standards (Hunko, Ye., 2010).

Hunko's pedagogical influence has been equally significant. As head of the Department of Vocal and Choral Studies, he trained several generations of conductors who today shape the choral landscape in Ukraine and abroad. His teaching philosophy emphasized artistic responsibility, national consciousness, and refined musical taste — values that became foundational for the regional choral-conducting tradition.

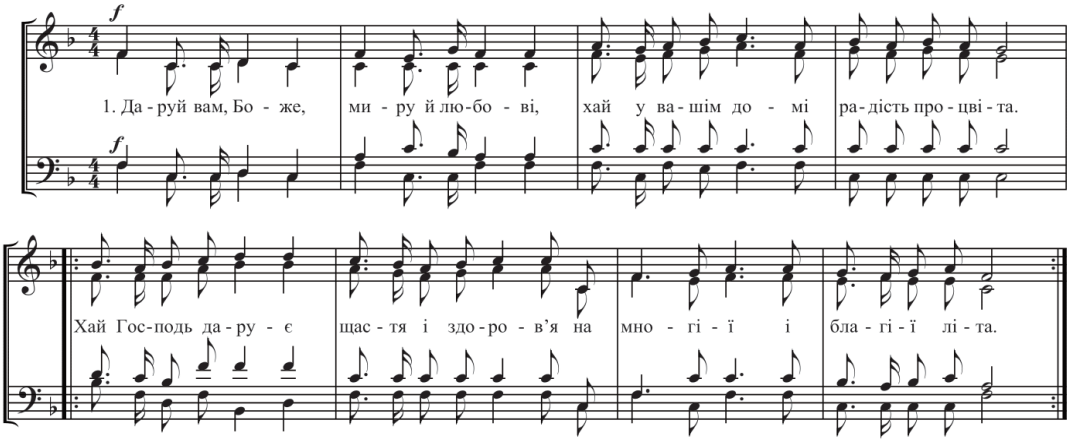


Pic.1: Fragment of the arrangement of the carol “Silent Night” by Yevhen Hunko (manuscript).

Artistic Activity of Volodymyr Semchyshyn

Volodymyr Semchyshyn, Honored Worker of Culture of Ukraine, and associate professor of the Faculty of Arts at Ternopil National Pedagogical University - another influential figure in the choral culture of Ternopil, made his contribution at the intersection of academic and community-based musical practice. Alongside teaching at the Faculty of Arts and serving as head of the department, Semchyshyn conducted amateur and parish choirs, and worked with the symphonic-jazz orchestra of the Ternopil Philharmonic (Oronovska, L., 2018). His artistic interests embraced sacred, folk, and popular choral genres, reflecting an orientation toward a broad and diverse audience.

Semchyshyn is widely recognized for his choral harmonizations, especially those intended for church choirs. These works are distinguished by accessible harmonic language, based primarily on traditional tonal-functional relationships, clear voice leading, and comfortable tessitura suitable for non-professional ensembles. This accessibility enabled his arrangements to be adopted by numerous community choirs throughout the region, contributing to the vitality and continuity of parish singing traditions (see Pic. 2) .



Pic.2: Choral arrangement of “Mnohaya Lita”
by Volodymyr Semchyshyn (Semchyshyn, V., 1999)

Comparison of Arranging Approaches and Stylistic Focus

Thus, while Hunko’s arrangements are oriented toward professional ensembles, Semchyshyn created repertoire accessible to a wider range of performers, enabling choral culture to thrive simultaneously at academic and community levels. Both approaches are essential for sustaining the integrity of Ukrainian musical heritage.

Yevhen Hunko’s harmonic arrangements are distinguished by a complex polyphonic texture, flexible harmonic modulations, and a rich palette of timbral nuances. As a composer and arranger, he demanded a high level of vocal culture from performers, including refined ensemble coordination combined with precise intonation and technical excellence.

In contrast, Volodymyr Semchyshyn oriented his arrangements not only toward professional choirs but also toward a broad amateur audience. This orientation determined the character of his harmonizations, which are marked by a clear four-part structure (soprano, alto, tenor, bass), a natural vocal line, the use of a traditional cadential scheme (tonic–subdominant–dominant–tonic), and the preservation of natural breathing and textual expressiveness characteristic of church singing.

Despite their differences in stylistic focus and repertoire, the artistic legacies of Hunko and Semchyshyn are deeply interconnected. Both served as heads of the department of vocal and choral performance, both

educated generations of conductors, and both viewed choral singing as a bearer of Ukrainian cultural identity. Their contributions complement one another: Hunko strengthened the artistic standards of academic choral performance, while Semchyshyn ensured the spread of choral singing in communal and liturgical settings. Together, they represent two interrelated dimensions of regional choral culture — professional and communal — both of which are necessary for cultural continuity and vitality.

Conclusions.

The artistic and pedagogical achievements of Yevhen Hunko and Volodymyr Semchyshyn reveal two complementary dimensions of choral culture in Ternopil: the professional academic tradition and the broad community-based practice of liturgical and amateur singing. Through their leadership of university choirs, parish ensembles, student collectives, and through their arrangement work and sustained teaching activity, both conductors ensured cultural continuity and contributed to the creative vitality of the region. They shaped aesthetic values, musical taste, and the ethical principles of choral performance for generations of conductors, performers, and educators.

Despite their profound influence on the musical life of the region, the figures of Hunko and Semchyshyn remain insufficiently represented in scholarly literature. Their artistic legacy is under-researched and requires broader recognition within contemporary Ukrainian musicology. The preservation, analytical interpretation, and continued performance of their choral arrangements hold significant potential for strengthening national identity and cultural memory. Therefore, further musicological research should be directed toward a systematic study of their creative output, pedagogical methodologies, and the historical role they played in forming the Ternopil choral school.

Their work constitutes a valuable cultural heritage that deserves continued scholarly attention and integration into modern choral performance practice — not only as a source of regional pride, but also as a meaningful contribution to the cultural landscape of Ukraine.

References

1. Hunko, Ye. (2010). Oi muzyku duzhe liubliu: Arrangements for Choir and Male Quartet. Ternopil: Department of Musicology, Methods of Music Education and Vocal and Choral Disciplines. [Published in Ukrainian]
2. Kaniuka, A. H., & Protsiv, L. Y. (2018). Creative activity of Yevhen Hunko's conducting class. In Artistic Activity in the Contemporary Sociocultural Space (25-year creative contribution of the Faculty of Arts of Ternopil Volodymyr Hnatiuk National Pedagogical University): Collective monograph (pp. 315–321). Ternopil. [Published in Ukrainian]
3. Oronovska, L. D. (2018). Cultural, educational and pedagogical activity of Volodymyr Semchyshyn. In Artistic Activity in the Contemporary Sociocultural Space (25-year creative contribution of the Faculty of Arts of Ternopil Volodymyr Hnatiuk National Pedagogical University): Collective monograph (pp. 322–330). Ternopil. [Published in Ukrainian]
4. Semchyshyn, V. (1999). Church Songs: Arrangements for Mixed Choir. Ternopil: Ternopil Regional Organization of the National League of Ukrainian Composers. [Published in Ukrainian]

SYNERGY OF MODERN TECHNOLOGIES AND ART AS A SACRAL FORMATIVE FORCE ON HUMAN PERCEPTION AND WILL: THE PROTESTANT VISUAL PARADIGM

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СИНЕРГЕТИЧНА ДІЯ СУЧАСНИХ ТЕХНОЛОГІЙ ТА МИСТЕЦТВА ЯК САКРАЛЬНОГО ЧИННИКА ФОРМУВАННЯ ПОЧУТТІВ І ВОЛІ ЛЮДИНИ: ПРОТЕСТАНТСЬКИЙ ВІЗУАЛЬНИЙ ПАРАДИГМАТ

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Вступ

Сучасна культура функціонує в умовах постійної взаємодії технологічних, візуальних і світоглядних чинників, які формують не лише зовнішні образи дійсності, але й глибинні механізми людського сприйняття, емоцій та волі. У цьому контексті мистецтво перестає бути автономною естетичною практикою і набуває ознак сакральної дії, що опосередковано впливає на підсвідомі рівні особистості. Особливої ваги набуває синергетична взаємодія сучасних цифрових технологій та мистецтва, яка формує нові типи культурного досвіду, нові моделі просторового мислення та нові форми сакрального переживання.

Одним із малодосліджених, але надзвичайно впливових чинників такого процесу є протестантська культура та її мистецькі прояви, зокрема у сфері організації сакрального простору домів молитви. Саме тут мінімалізм, аскеза, редукція декоративного надлишку та інтеграція сучасних технологій створюють особливий тип візуальної атмосфери, що діє не на зовнішнє споглядання, а на внутрішнє переживання людини.

Сакральна природа мистецтва та підсвідомі механізми впливу

Мистецтво в своїй глибинній природі завжди мало сакральний вимір, навіть у тих історичних формах, де воно декларувало секулярність. Його вплив не обмежується рівнем раціонального аналізу, а проникає у сферу підсвідомого, формуючи систему образів, асоціацій і внутрішніх установок. Підсвідомим рушієм мистецтва є так звана «релігія особистості» — сукупність глибинних переконань, екзистенційних орієнтирів і світоглядних архетипів, що формуються під впливом спадковості, виховання, соціального середовища та культурних мейнстримів.

Формотворча дія мистецтва є відображенням внутрішньої сакральної аури митця — складного психокультурного утворення, яке виникає як результат поєднання природних задатків, духовного досвіду та інформаційного впливу сучасних технологій. У добу цифровізації ці технології не лише транслюють культурні смисли, але й активно корелюють із домінантними культурними наративами, що лобіюються потужними соціальними та ідеологічними групами.

Синергетика технологій і мистецтва у формуванні сприйняття

Сучасні цифрові технології — мультимедійні системи, проєкційні середовища, світлові та аудіовізуальні інструменти — стають не просто технічними засобами, а повноцінними елементами художньої мови. Їх інтеграція в мистецькі та сакральні простори створює нову якість естетичного досвіду, де технологія виступає посередником між матеріальним і нематеріальним.

У цьому сенсі синергетична дія мистецтва й технологій полягає у зосередженні уваги людини на внутрішніх процесах переживання. Візуальна стриманість, технологічна чистота та логічна організація простору сприяють концентрації, рефлексії та тривалому перебуванню в такому середовищі без психоемоційного перевантаження.

Протестантська візуальна культура як аскетична модель сакрального простору

Протестантське мистецтво у всіх його проявах — від архітектури до інтер'єру та мультимедійних форм — характеризується принциповою орієнтацією на аскезу, простоту і функціональність. Особливе значення має внутрішнє оздоблення домів молитви, де відсутність надмірної декоративності формує специфічне сприйняття сакрального простору як серйозного, зосередженого та інтелектуально насиченого.

Редукція візуального надлишку до помірного мінімуму сприяє перенесенню акценту з зовнішнього на внутрішнє. Чим більше мінімалізму та сучасних цифрових технологій інтегровано в простір

дому молитви, тим сучаснішим він сприймається відвідувачами. Водночас такий простір автоматично набуває більшої цінності у мистецькому вимірі для вірян і прихожан, оскільки асоціюється з актуальністю, інтелектуальною чесністю та екзистенційною глибиною.

Внутрішнє переживання як домінанта сакрального досвіду

У протестантському сакральному просторі вся увага людини концентрується на власному внутрішньому переживанні, яке часто є значно яскравішим і впливовішим за зовнішні образи. Такий підхід створює психологічний комфорт для тривалого перебування у просторі, формуючи відчуття стабільності, тиші та зосередженості.

Сакральність у цьому випадку не нав'язується через символічну надмірність, а народжується як внутрішній досвід, що активізується завдяки візуальній стриманості та технологічній нейтральності середовища. Саме ця особливість робить протестантський сакральний простір одним із найбільш показових прикладів сучасної синергії мистецтва, технологій і духовного досвіду.

Висновки

Синергетична взаємодія сучасних технологій та мистецтва виступає потужним сакральним чинником формування почуттів і волі людини в умовах сучасної культури. Мистецтво, будучи носієм підсвідомих світоглядних структур, реалізує свою формотворчу дію через внутрішню сакральну ауру митця та культурний контекст епохи.

Протестантська візуальна культура, зокрема у сфері організації сакрального простору домів молитви, демонструє ефективну модель аскетичного, мінімалістичного та технологічно інтегрованого середовища, яке сприяє глибокому внутрішньому переживанню. Саме концентрація на внутрішньому досвіді, а не на зовнішній репрезентації, робить такий простір сучасним, ціннісно насиченим і мистецьки значущим для сучасної людини.

References

1. Benjamin, W. (2008). *The Work of Art in the Age of Mechanical Reproduction*. London: Penguin Books.
2. Bourriaud, N. (2002). *Relational Aesthetics*. Dijon: Les presses du réel.
3. Eliade, M. (1987). *The Sacred and the Profane*. New York: Harcourt Brace Jovanovich.
4. Heidegger, M. (1971). *Poetry, Language, Thought*. New York: Harper & Row.
5. Panofsky, E. (1991). *Meaning in the Visual Arts*. Chicago: University of Chicago Press.
6. Tillich, P. (1959). *Theology of Culture*. New York: Oxford University Press.
7. Weber, M. (2002). *The Protestant Ethic and the Spirit of Capitalism*. London: Routledge.

Biological sciences

MİCROPLASTİCS İN THE FOOD CHAİN: ENVİRONMENTAL AND CHEMİCAL RİSKS

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Abstract

Microplastics have emerged as one of the most significant environmental pollutants of the 21st century. These particles, typically smaller than 5 mm, originate from the fragmentation of larger plastic materials or are intentionally produced for industrial and commercial applications. Due to their small size, persistence, and chemical properties, microplastics are widely distributed in terrestrial and aquatic ecosystems. They enter the food chain through water, soil, and atmospheric pathways, posing potential risks to both ecosystems and human health. Microplastics can adsorb toxic substances such as heavy metals, pesticides, and persistent organic pollutants, acting as carriers of harmful chemicals. Moreover, they may release additives including plasticizers, stabilizers, and flame retardants. This study examines the main sources of microplastics, their chemical characteristics, and their pathways into the food chain. It also evaluates their environmental and health risks. The findings highlight the need for improved waste management, reduction of plastic consumption, and the development of sustainable materials to minimize microplastic pollution.

Keywords: microplastics, food chain, environmental pollution, chemical risks, human health

Introduction

Plastic production has increased dramatically over the past decades due to its low cost, durability, and versatility. Global plastic production has risen from approximately 1.5 million tons in the 1950s to over 400 million tons in recent years, reflecting its widespread application in packaging, construction, transportation, electronics, and consumer products. While plastics have undoubtedly contributed to economic development and convenience, their extensive use has resulted in significant environmental pollution. One of the most concerning consequences of this pollution is the formation of microplastics, which are defined as plastic particles smaller than 5 millimeters in size. These particles are classified as either primary microplastics, which are intentionally manufactured small particles used in products such as exfoliants, industrial abrasives, and raw materials for plastic manufacturing, or secondary microplastics, which result from the breakdown of larger plastic debris due to mechanical, photochemical, and biological processes [1].

Microplastics are now recognized as a pervasive environmental contaminant, detected in marine and freshwater ecosystems, terrestrial soils, atmospheric deposits, and even in remote polar regions and deep ocean sediments. Their persistence is largely due to the inherent durability and chemical stability of synthetic polymers, which resist natural biodegradation. Consequently, microplastics can accumulate over time, creating reservoirs of pollution in diverse ecological niches [2]. Due to their small size, these particles are readily ingested by a wide variety of organisms, ranging from plankton and invertebrates to fish, birds, and terrestrial animals, thereby entering and propagating through food webs. The incorporation of microplastics into the food chain has been demonstrated by numerous studies reporting their presence in seafood such as fish, mollusks, and crustaceans, as well as in processed products including drinking water, table salt, honey, fruits, and vegetables [3, 4]. These findings raise important concerns about human exposure and potential health implications.

From a chemical standpoint, microplastics are far from inert. They are composed of polymeric matrices to which a variety of additives are incorporated during manufacturing. These additives may include plasticizers, stabilizers, colorants, UV absorbers, and flame retardants, many of which are known to be bioactive or toxic. During environmental exposure, these chemicals can leach from microplastics into surrounding media, contributing to chemical pollution [5]. In addition, the hydrophobic surfaces of microplastics have a strong tendency to adsorb persistent organic pollutants (POPs), heavy metals, and other toxic substances present in the environment. This adsorption not only enhances the chemical load of

microplastics but also facilitates their transport across ecosystems, increasing the risk of contaminant transfer to organisms that ingest them [6].

The ecological and chemical risks of microplastics are therefore multifaceted. Physically, ingestion of microplastics by organisms can cause internal abrasions, intestinal blockages, reduced feeding efficiency, and energy depletion. Chemically, the additives and adsorbed pollutants may induce oxidative stress, endocrine disruption, inflammation, and other toxic effects, as demonstrated in laboratory studies with fish and invertebrates [7]. These combined effects highlight the urgent need for comprehensive assessment of microplastics in the food chain and their potential impacts on ecosystem health and human well-being.

Given the growing global concern over microplastics, research efforts are increasingly focused on quantifying their occurrence in food, understanding their behavior in the environment, and evaluating the biological and chemical mechanisms by which they affect organisms and humans. Furthermore, strategies for reducing microplastic pollution, such as improved waste management, biodegradable alternatives, and regulatory restrictions on microbeads and industrial sources, are gaining attention [8]. Understanding both the environmental persistence and chemical interactions of microplastics is therefore essential to assess their risk accurately and develop effective mitigation measures.

Literature review

Microplastics, defined as plastic particles smaller than 5 mm, have emerged as a major environmental concern due to their persistence, ubiquity, and potential impact on ecosystems and human health. These particles originate from the degradation of larger plastic debris (secondary microplastics) or are manufactured intentionally for use in personal care products, industrial processes, and packaging (primary microplastics) [1].

The presence of microplastics in aquatic environments has been widely documented. Rivers, lakes, and oceans act as major reservoirs for these particles, which are ingested by a wide range of organisms, from plankton to fish and higher trophic levels [2]. Studies indicate that microplastics can enter the food chain at multiple points, leading to bioaccumulation in aquatic species and potential biomagnification across trophic levels [3]. For example, zooplankton, a primary food source for many fish species, readily ingests microplastic particles, which can then be transferred to fish and subsequently to human consumers [4].

The environmental risks associated with microplastics are multifaceted. Physically, microplastics can cause internal abrasions, blockages, and reduced feeding efficiency in aquatic organisms [5]. Chemically, these particles often act as vectors for persistent organic pollutants (POPs), heavy metals, and additives such as plasticizers and flame retardants. Due to their hydrophobic surfaces and large surface area, microplastics can adsorb and concentrate these toxic compounds, increasing exposure risk for organisms that ingest them [6]. Laboratory studies have demonstrated that the ingestion of contaminated microplastics can lead to oxidative stress, inflammation, and impaired reproduction in fish and invertebrates [7].

Moreover, the potential human health implications of microplastics through dietary exposure are gaining increasing attention. Seafood such as fish, crustaceans, and mollusks are primary sources of microplastic ingestion in humans, although the extent of absorption and potential toxicological effects are still under investigation [8]. Some studies suggest that chemicals associated with microplastics, including bisphenol A (BPA) and phthalates, can disrupt endocrine function, cause inflammatory responses, and may pose long-term risks to metabolic and reproductive health [9].

The distribution and accumulation of microplastics in terrestrial and marine food chains are influenced by particle size, shape, polymer type, and environmental factors. Smaller particles, such as nanoplastics, are of particular concern due to their potential to penetrate biological membranes and enter circulatory systems [10]. Recent research also highlights the role of sediment-dwelling organisms and filter feeders as significant mediators of microplastic transfer and bioaccumulation [11].

Despite the growing body of literature, knowledge gaps remain regarding the long-term ecological and human health risks of microplastics. Standardized methods for sampling, detection, and quantification of microplastics in food items and environmental matrices are still under development, which limits comparability across studies [12]. Furthermore, while laboratory studies have elucidated mechanistic pathways of microplastic toxicity, field-based assessments that reflect realistic exposure scenarios are needed to fully understand the implications for food safety and public health [13].

In summary, current evidence demonstrates that microplastics pose significant environmental and chemical risks through their entry into the food chain. Both physical and chemical effects threaten aquatic organisms and potentially human health. Comprehensive monitoring, standardized methodologies, and multidisciplinary research are essential to assess the scale of the problem and develop effective mitigation strategies [1–13].

Materials and Methods

This study is based on a comprehensive review and analysis of recent scientific literature related to microplastics in the environment and food chain. Data were collected from peer-reviewed articles, international environmental reports, and scientific databases such as Web of Science, Scopus, and Google Scholar.

The methodological approach included:

- Analysis of sources and types of microplastics in environmental compartments.
- Evaluation of the chemical composition and properties of microplastics.
- Examination of pathways through which microplastics enter the food chain.
- Assessment of ecological and human health risks based on published studies.

The collected information was systematically compared and synthesized to identify common patterns, major risks, and research gaps in the field of microplastic contamination.

Results and Discussion

Microplastics originate from both primary and secondary sources. Primary microplastics are manufactured at microscopic sizes for specific applications, such as cosmetic microbeads, industrial abrasives, and synthetic textile fibers. Secondary microplastics result from the breakdown of larger plastic items, including packaging materials, bottles, fishing gear, and plastic bags.

Environmental factors such as ultraviolet radiation, temperature fluctuations, mechanical abrasion, and biological activity contribute to the fragmentation of plastics into microplastics. Waste mismanagement and the extensive use of single-use plastics significantly increase the amount of microplastics released into the environment.

Microplastics are composed of various polymer types, including polyethylene (PE), polypropylene (PP), polystyrene (PS), polyethylene terephthalate (PET), and polyvinyl chloride (PVC). These polymers often contain chemical additives such as plasticizers, stabilizers, pigments, and flame retardants.

Due to their hydrophobic surfaces and large surface area, microplastics can adsorb toxic substances from the environment. These may include heavy metals, pesticides, and persistent organic pollutants. As a result, microplastics can act as carriers of hazardous chemicals, increasing their ecological impact.

Microplastics enter the food chain through multiple pathways. In aquatic ecosystems, plankton and small invertebrates ingest microplastics, mistaking them for food particles. These organisms are then consumed by fish and other predators, leading to the accumulation of microplastics along the trophic levels.

In terrestrial environments, microplastics can enter agricultural soils through sewage sludge, irrigation with contaminated water, and plastic mulching. Crops may absorb microplastics or become contaminated through surface deposition.

Human exposure occurs mainly through the consumption of seafood, drinking water, salt, and other contaminated food products. Inhalation of airborne microplastics also represents a potential exposure pathway.

Microplastics pose several environmental risks. In aquatic organisms, ingestion of microplastics may cause physical damage, reduced feeding, impaired growth, and reproductive problems. The chemical additives and adsorbed pollutants associated with microplastics may lead to toxic effects, oxidative stress, and endocrine disruption.

For humans, the long-term health effects of microplastic exposure are still under investigation. However, potential risks include inflammation, cellular damage, and the transfer of toxic substances into the body. The presence of microplastics in drinking water and food products highlights the importance of monitoring and regulation.

Conclusion

Microplastics have become a widespread environmental pollutant with significant ecological and chemical risks. Their small size, persistence, and ability to adsorb toxic substances enable them to enter the food chain and accumulate in living organisms. Both aquatic and terrestrial ecosystems are affected by microplastic contamination, and human exposure occurs mainly through food and water consumption.

The study emphasizes the urgent need for improved waste management practices, reduction of single-use plastics, and the development of biodegradable materials. Further research is required to better understand the long-term health impacts of microplastics and to develop effective strategies for mitigating their environmental effects.

References

1. Andrady, A. L. (2011). Microplastics in the marine environment. *Marine Pollution Bulletin*, 62(8), 1596–1605.

2. Andrady, A. L. (2011). *Microplastics in the marine environment*. Marine Pollution Bulletin, 62(8), 1596–1605. https://doi.org/10.1016/j.marpolbul.2011.05.030

3. Cole, M., Lindeque, P., Halsband, C., & Galloway, T. (2011). Microplastics as contaminants in the marine environment: a review. *Marine Pollution Bulletin*, 62(12), 2588–2597.

4. Cole, M., Lindeque, P., Halsband, C., & Galloway, T. S. (2011). *Microplastics as contaminants in the marine environment: A review*. Marine Pollution Bulletin, 62(12), 2588–2597. https://doi.org/10.1016/j.marpolbul.2011.09.025

5. Galloway, T. S., & Lewis, C. N. (2016). Marine microplastics spell big problems for future generations. *Proceedings of the National Academy of Sciences*, 113(9), 2331–2333.

6. Galloway, T. S., & Lewis, C. N. (2016). *Marine microplastics spell big problems for future generations*. Proceedings of the National Academy of Sciences, 113(9), 2331–2333. https://doi.org/10.1073/pnas.1600715113

7. Kosuth, M., Mason, S. A., & Wattenberg, E. V. (2018). *Anthropogenic contamination of tap water, beer, and sea salt*. PLoS ONE, 13(4), e0194970. https://doi.org/10.1371/journal.pone.0194970

8. Li, J., Liu, H., & Chen, J. P. (2018). Microplastics in freshwater systems: A review on occurrence, environmental effects, and methods for microplastics detection. *Water Research*, 137, 362–374.

9. Lithner, D., Larsson, Å., & Dave, G. (2011). *Environmental and health hazard ranking and assessment of plastic polymers based on chemical composition*. Science of the Total Environment, 409(18), 3309–3324. https://doi.org/10.1016/j.scitotenv.2011.04.038

10. Rist, S., Carney Almroth, B., Hartmann, N. B., & Karlsson, T. M. (2018). *A critical perspective on early communications concerning human health aspects of microplastics*. Science of the Total Environment, 626, 720–726. https://doi.org/10.1016/j.scitotenv.2018.01.094

11. Sharma, S., & Chatterjee, S. (2017). *Microplastic pollution, a threat to marine ecosystem and human health: a short review*. Environmental Science and Pollution Research, 24, 21530–21547. https://doi.org/10.1007/s11356-017-9910-8

12. Wright, S. L., & Kelly, F. J. (2017). Plastic and human health: a micro issue? *Environmental Science & Technology*, 51(12), 6634–6647.

13. Wright, S. L., Thompson, R. C., & Galloway, T. S. (2013). *The physical impacts of microplastics on marine organisms: a review*. Environmental Pollution, 178, 483–492. https://doi.org/10.1016/j.envpol.2013.02.031

EFFECT OF CO^{2+} IONS ON ION TRANSPORT PROCESSES IN THE PLASMA MEMBRANE OF CHARA GYMNOPHYLLA CELLS

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Abstract

Heavy metal pollution, including Co^{2+} ions, is an important environmental factor affecting the physiology of aquatic plants. Green algae, *Chara gymnophylla*, are widely used as a model for bioelectric energy production due to their large and accessible size. In this study, the effect of Co^{2+} ions on plasma membrane ion transport properties was investigated using microelectrode technology. Changes in membrane potential, ion permeability, and Co^{2+} concentration were measured. The results indicate that Co^{2+} exposure causes measurable changes in ion transport dynamics that typically impact homeostasis. These effects are likely mediated by ion channels and Co^{2+}-mediated membrane transport mechanisms. These findings provide insights into how heavy metals influence plant bioelectrical behavior and what mechanisms enhance the effects of metal stress responses. Overall, this study contributes to the knowledge of environmental toxicology in aquatic ecosystems and highlights the importance of monitoring the effects of heavy metals on plant physiology.

Keywords: Chara gymnophylla, Co^{2+}, plasmalemma, ion transport, microelectrode measurement, heavy metal stress.

The plasma membrane of plant cells plays the role of the main functional boundary between the cell and the external environment. The biological membrane plays the role of an important biological structure by ensuring the selective transport of ions as well as other substances. Ion transport properties are closely related to the metabolic activity of the cell, osmotic balance, and the ability to adapt to various stress factors. The processes occurring in the membrane and the functional properties of the membrane depend on a number of factors. The most important of these are external environmental factors. Heavy metal ions occupy a special place among external environmental factors. They significantly affect the functional and bioelectric parameters of the biological membrane [1].

Heavy metals affect living organisms directly or indirectly. They can pose a threat to the survival of both plants, animals, and humans. Although heavy metals are physiologically important as microelements for plants in certain cases, they have a toxic effect at the cellular level in high concentrations and cause plant death. According to literature data, heavy metal ions can affect the functional activity of the plasma membrane. They can affect the permeability of the membrane, the activity of ion channels, and alter the stability of the membrane potential. As a result of these changes, ion homeostasis is disrupted and metabolic processes within the cell cannot function normally [1].The effect of heavy metal ions is not limited to this. In addition, they can also affect the structure of the lipid layer, disrupting its integrity and changing the functional state of membrane proteins. It is noted in the literature that heavy metal ions enhance the peroxidation of membrane lipids, affecting the physical properties and elasticity of the plasmalemma, which in turn leads to a decrease in the efficiency of ion transport processes [1,5].

In addition, under heavy metal stress, the energy balance and electrochemical potential differences of cells can also change. The activity of ion pumps is related to ion pumps, and a decrease in the functional activity of these systems can ultimately lead to a general weakening of cell functions. In particular, changes in the activity of proton pumps directly affect changes in membrane potential and secondary active transport mechanisms [2].

The plasma membrane responds to the effects of heavy metals by decreasing the activity of ion transport systems, mainly the H+-ATPase enzyme. Studies have shown that heavy metal ions can modify the electrophysiological parameters of the cell by affecting the energy-dependent transport mechanisms associated with the membrane [2].

The effect of heavy metals on the modification of H+-ATPase activity of the plasma membrane of plant cells was studied. In plants kept under stress with 10 M and 100 M Cd, Cu or Ni for 2 hours, the hydrolytic activity of H+-ATPase in the plasma membranes of root cells decreased. In addition, a decrease in transport activity was observed. It was observed that they did not affect the level of gene expression during exposure to heavy metals. However, the level of H+-ATPase mRNA in the plasma membrane of plant cells exposed to 100

M heavy metals decreased significantly. As a result of the effect of heavy metals on biomembranes, a decrease in the activity of H+-ATPase was confirmed as a result of dephosphorylation of enzyme proteins. In general, this information indicates that the change in enzymes due to heavy metal ions is mainly associated with the modification of the translational sequence of proteins, which leads to a change in the activity of membrane processes [6].

Although heavy metals such as Co^{2+}, Cu^{2+}, Zn^{2+}, Mn^{2+}, Fe^{2+}, Ni^{2+} are considered essential for plant metabolism, their effects can be toxic when present in excessive amounts. For example, Cu^{2+} is an essential element involved in both photosynthesis and a number of electron transport reactions. Enzymes are activated by Zn^{2+} and Mn^{2+}. In general, it can be said that although high concentrations of divalent cations have a negative effect on plant cells, especially on the plasma membrane, their low concentrations have a stimulating effect on plants. Thus, when these ions do not reach the roots, specific deficiency symptoms appear in plants. However, at high concentrations, these metals can be extremely toxic and can result in symptoms such as chlorosis, necrosis, growth retardation, discoloration of leaves, and inhibition of root growth. The toxic effect at the cellular level occurs by binding to sulfhydryl groups in proteins, inhibiting enzyme activity or It can occur by affecting protein function or by causing a deficiency of other essential ions. (Article 3 4) There are 3 classes of membrane transporters involved in the transport of heavy metals in various organisms and playing an important role in plants: heavy metal (CPx-type) ATPases, members of the innate resistance-associated macrophage protein (Nramp) family, and members of the cation diffusion facilitator (CDF) family. Based on studies conducted in various organisms, it has been determined that the main features of these transporters in plants are important in terms of structure, function, and regulation [7].

The electrical properties of plasma membranes (PM) depend largely on the ionic composition of the environment to which the cell is exposed, and these properties play a crucial role in the distribution of ions on the outer surface of the PM, as well as in their transport through the PM. The uptake of cations simultaneously present in the environment by plants and how they affect their toxic effects have been investigated through the prism of the electrical properties of PMs.

An increase in the concentration of cations or a decrease in the pH value weakened the negative value of the electric potential on the outer surface of the plasma membrane ($\psi(0)(o)$). This weakening led to a decrease in the effective activity of metal cations on the membrane surface, while at the same time increasing the activity of anions such as $H_2AsO_4^-$. In addition, the decrease in the negativity of ($\psi(0)(o)$) increased the transmembrane potential difference between the outer and inner surfaces of the membrane, which in turn strengthened the electromotive force for the entry of cations into the cell and weakened this force for the absorption of anions. Analyses based on electrostatic models showed that the level of ion absorption and toxicity depend on two main effects of ($\psi(0)(o)$): a change in the activity of ions on the plasma membrane surface and a modification of the transmembrane potential difference gradient between the surfaces. This study provides a new perspective on the mechanisms of interaction between plants and ions, and expands the existing theoretical framework for the bioavailability of ions and the assessment of toxicity. expands the framework and reveals its practical importance in assessing the risk of metals and metalloids in natural waters and soils [8].

The initial results on the electrical parameters of biomembranes were obtained from the studies conducted by Blix (1930) and Osterhaut (1922) on plant objects. Due to the complexity of the membranes of plant cells, the problem of regulating their electrogenic activity has not been fully solved to this day. Plant cells have two membranes that form an electrical circuit in series with each other. The process of passive diffusion of ions and active transport of ion pumps takes place in the membrane. Thus, the final electrogenic activity of cell membranes is formed as a result of both passive diffusion of ions and the activity of ion pumps.

Research object and methods used

One of the suitable objects for studying the effect of heavy metal ions on the cell membrane is the algae *Chara gymnophylla*. Because chara algae, including *Chara gymnophylla*, have large cell sizes and clearly expressed bioelectric properties (Picture 1). Therefore, it is a suitable model organism for studying the ion transport mechanisms of the plasma membrane. It has also been shown in the literature that it is possible to study the structural and functional properties of the plasmalemma of *Chara* species by electrophysiological methods [3].*Chara gymnophylla* was one of the earliest charophyte species recorded in Serbia in the late 19th and early 20th centuries, and was the second most common species in the country at that time. However, due to taxonomic misinterpretations that developed over time, some of the finds attributed to this species were not actually attributed to *Chara squamosa*.

Picture 1.*Chara gymnophylla*

In Serbia, *Chara gymnophylla* was long considered to be *C. vulgaris*, and therefore was not registered as an independent species in the flora of the country. Recent clarifications in the taxonomic definition of *C. squamosa* have necessitated a reassessment of the rich material consisting of *C. gymnophylla, C. vulgaris, C. nitelloides* and *C. rohlenae* specimens stored in the BEOU herbarium collection [4].

Experimental studies on charophytes have contributed to the determination of the kinetic properties of the primary active transport components in the plant cell plasma membrane, as well as to the determination of the mechanisms of action of a number of xenobiological and pharmacological agents on the plasma membrane and other modifiers of the transport properties of the biomembrane (Musayev, 2012; Musayev et al., 2009). Charophytes are not limited to studying only the mentioned processes as a test object, but also provide an opportunity to study the transport properties of the plasma membrane of stress factors. Therefore, this algal cell seems promising for recognizing adaptive responses to modifications of the transport properties of the plasma membrane [9].

We used standard microelectrode techniques to measure plant cell parameters.This technique is used to measure bioelectrical parameters in living cells and tissues.For this purpose, microelectrodes with micrometer-sized tips are prepared.The prepared microelectrodes are filled with an electrolyte solution, which is done to ensure electrical conductivity.

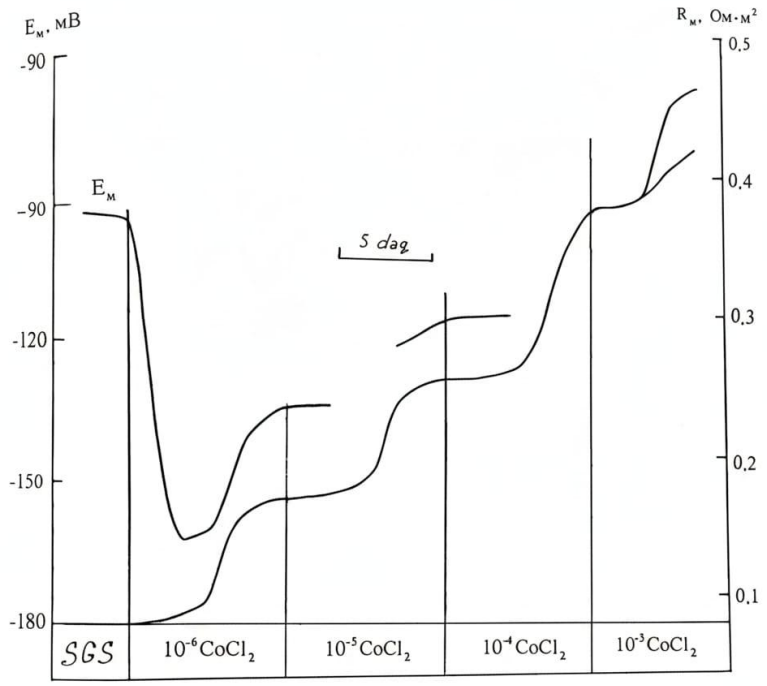
Micrometer-sized electrodes were not widely used in electrochemical research until the 1980s, but interest in them has grown exponentially in recent years.A microelectrode is usually characterized as an electrode whose dimensions are comparable to the thickness of the diffusion layer and which exhibits certain relationships depending on its size. For a small electrode, the diffusion flux combines both transient and steady-state components. When the electrode is sufficiently small, the steady-state diffusion process dominates except for very short time intervals. It is this behavior that underlies the widespread use of microelectrodes in the study of electrode kinetics and in electroanalytical applications [10].

Interstitial cells of *Chara gymnophylla* were used during the experiment.Measurements of key electrophysiological parameters, including membrane resistance R_m and plasma and vacuolar membrane potential φ_m, were performed using Hogg's two-electrode method, which was developed specifically for cylindrical cells (Hogg et al., 1968) [9].The object under study is placed in a special measuring chamber. It is inserted into the cell via a microelectrode using a micromanipulator. The difference between the comparison and reference electrodes is then recorded using an amplifier.

Conclusion and their discussion

After the microelectrode is inserted into the entire cell vacuole, the generation of an action potential is recorded. This process is characterized by a temporary cessation of cytoplasmic flow and a gradual convergence of the membrane potential towards a stable level.Conversely, when the tip of the measuring

microelectrode (ME) is inserted into the cytoplasm, the membrane potential instantly reaches a stationary level, no action potential is observed, and the speed of movement of the cytoplasm does not change [11].



Picture 2.Changes in membrane potential (E_m) and resistance (R_m) upon sequential addition of 10^{-5},10^{-4},10^{-3} M concentrations of Co^{2+} to *Chara gymnophylla* cells.

Analysis of the bioelectric responses of *Chara gymnophylla* cells upon the introduction of Co^{2+} ions into the medium has shown that the Co^{2+} cation diffuses into all compartments of the cell in a very short time. This fact is confirmed by the change in the bioelectric response of the plasmalemma upon the addition of Co^{2+} to the nutrient medium. The characteristic bioelectric response for the cells studied under the influence of Co^{2+} ions is expressed by hyperpolarization of the plasmalemma in the range of 30÷90 mV and an approximately twofold increase in membrane resistance.

References

1. Hall, J. L. (2002). Cellular mechanisms for heavy metal detoxification and tolerance. Journal of Experimental Botany, 53(366), 1–11.

2.Janicka-Russak, M., & Kabała, K. (2008). Response of plasma membrane H^+-ATPase to heavy metal stress in plant roots. Journal of Experimental Botany, 59(13), 3721–3728.

3. Beljanski, M. (1995). Plasma membrane characteristics of Chara gymnophylla. Plant Science, 110(2), 121–130.

4. Trbojević, I., Marković, A., Šinžar-Sekulić, J., Subakov-Simić, G., & Romanov, R. (2024). Chara squamosa (Characeae, Charophyceae) in Serbia – insights from the taxonomic revision of the BEOU charophyte collection and recent field records. Botanica Serbica, 48(1), 85–92.

5. Taiz, L., Zeiger, E., Møller, I. M., & Murphy, A. (2015). Plant Physiology and Development (6th ed.). Sinauer Associates.

6. Janicka-Russak, M., & Kabała, K. (2008). Response of plasma membrane H^+-ATPase to heavy metal stress in Cucumis sativus roots. Journal of Experimental Botany, 59(13), 3721–3731.

7. Emerging mechanisms for heavy metal transport in plants. (2000). Biochimica et Biophysica Acta (BBA) – Biomembranes, 1465(1–2), 104-126.

8. Plasma membrane surface potential: dual effects upon ion uptake and toxicity. (2010). Journal of Experimental Botany, 61(7), 1771-1781.

9. Hasanova, A. A., Najafaliyeva, S. A., Aliyeva, P. F., & Musayev, N. A. (2018). Electrophysiological parameters of cellular wall and plasmatic membrane of Chara fragilis cells. Advances in Biology & Earth Sciences, 3(1), 60–68.

10. Scharifker, B. R. (1992). Microelectrode techniques in electrochemistry. In Modern Aspects of Electrochemistry (Vol. 22, pp. 467–519).

11. Beilby M.J Facters controlling the K^+ conductance in Chara. J.Membr.Biol.,1986,v.93,№ 1,p.187-193.

Chemical sciences

THE INFLUENCE OF KYAGRIZ AND SPRING WATER ON THE HEALTH OF THE POPULATION ON THE EXAMPLE OF THE NAKHCHIVAN AUTONOMOUS REPUBLIC

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УДК 543-34.35

ВЛИЯНИЕ КЯГРИЗНОЙ И РОДНИКОВОЙ ВОДЫ НА СОСТОЯНИЕ ЗДОРОВЬЯ НАСЕЛЕНИЯ НА ПРИМЕРЕ НАХЧЫВАНСКОЙ АВТОНОМНОЙ РЕСПУБЛИКИ

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Abstract

The purpose of this work is an attempt to give a general description of groundwater in the Nakhchivan Autonomous Republic, as well as to outline the prospects and main problems associated with their use. The article deals with the practical and theoretical problems of the hydrogeology of the Autonomous Republic - the formation of the chemical composition of groundwater, the patterns of distribution and formation of fresh, kagriz and spring waters. An environmental, sanitary and epidemiological requirement for the quality of groundwater for drinking has been analysed. The purpose of the experimental study was to assess the state of groundwater from private water intake facilities used by the population in the Autonomous Republic as sources of economic and drinking water supply.

This is a living testimony to the wealth of the bowels of the Nakhchivan Autonomous Republic, groundwater, which is the most valuable mineral in our region.

Аннотация

Целью данной работы является попытка дать общую характеристику подземным водам Нахчыванской Автономной Республики, а также обозначить перспективы и основные проблемы, связанные с их использованием. В статье рассматриваются практические и теоретические проблемы гидрогеологии автономной республики – формирование химического состава подземных вод, закономерности распространения и формирования пресных, кягризных и родниковых вод. Проанализированы экологические и санитарно-эпидемиологические требования к качеству подземных вод для хозяйственно-питьевого водоснабжения. Целью экспериментального исследования явилась оценка состояния подземных вод из частных водозаборных сооружений, используемых населением автономной республики в качестве источников хозяйственно-питьевого водоснабжения.

Подробно описаны подземные воды Нахчыванской Автономной Республики, их химический состав, физические и гидро-экологические свойства. Это живое свидетельство богатства недр Нахчыванской Автономной Республики, подземными водами, которые являются самым ценным полезным ископаемым нашего края. В данной работе рассматриваются подходы, методы изучения пресных подземных вод, приводятся гидрологические и гидрохимические характеристики современного их состояния. Совокупность приведенных материалов дает нам возможность предложить ряд практических рекомендаций по рациональному использованию водных ресурсов автономной республики.

Keywords: Nakhchivan Autonomous Republic, groundwater, aquatic ecosystems, hydrochemical parameters.

Ключевые слова: Нахчыванская Автономная Республика, подземные воды, грунтовые воды, водных экосистем, гидрохимические параметры.

Экологические проблемы - нехватка водных ресурсов, загрязнение и деградация водных экосистем прямо влияют в регионе на экономическое развитие и социальные проблемы, такие как бедность, вынужденная миграция, ухудшение качества жизни и здоровья населения [1]. Повышение надежности и качества водоснабжения населения питьевой водой является одной из первоочередных социальных проблем, так как здоровье населения в значительной мере зависит от уровня безопасности питьевой воды.

Подземные воды подразделяются на питьевые, качественный состав которых отвечает нормативным требованиям пригодности для питья, бытовых нужд человека, и технические, предназначенные для использования в технических целях. Подземные воды области активного воднообмена связаны с атмосферными осадками, имеют инфильтрационное происхождение, играют важную роль в гидрологическом цикле; их динамические ресурсы преобладают над статическими. Основные ресурсы подземных вод хозяйственно-питьевого назначения в автономной республике связаны именно с этими водами. Технические воды имеют различный химический состав. Общее состояние водного объекта определяется его гидрохимическими параметрами [2, 3]. Эти параметры определяются путем анализа в лаборатории или непосредственно возле водоемов. У водоемов определяются следующие гидрохимические параметры воды: водородный индекс (pH) водной среды, количество растворенного кислорода, минеральность (карбонаты и углеводороды, сульфаты, хлориды, сухие остатки, жесткость, ионы кальция, магния, натрия и нитрита), биогенные элементы, фториды, общее количество железа в воде [4]. Оценка уровня загрязненности подземных вод проведена по единой методике. При этом за основу взята система интегральной оценки качества подземных вод, предложенная А.П. Белоусовой [5, 5], которая предусматривает расчет суммарного коэффициента загрязнения (СКЗ) по формуле СКЗ = $\sum C_i$/ ПКД, где C_i –концентрация i-го компонента, ПДК-предельно допустимая концентрация i-го компонента, утвержденная для оценки качества воды, используемой для питьевого водоснабжения.

На основании значений СКЗ приняты следующие категории загрязненности подземных вод: 1) СКЗ < 1 – условна чистая; 2) СКЗ = 1-5 – слабозагрязненная; 3) СКЗ = 5-10 – весьма загрязненная; 4) СКЗ = 10-20 – очень загрязненная; 5) СКЗ = 20-50 – грязная и очень грязная; 6) СКЗ > 50 – чрезвычайно грязная.

В числе важных задач в единой системе рационального природопользования входит также изучение водных ресурсов, поскольку они являются источником водоснабжения промышленных предприятий, сельскохозяйственного производства и коммунально-бытового хозяйства. Немаловажна значимость водных экосистем как объектов рекреационного и лечебно-оздоровительного значения. Среди минеральных источников по гидрохимическим показателям преобладают углекислые, мышьяковые, борные и радоновые которые успешно используются в рекреационных и бальнеологических целях и являются популярными объектами туристических маршрутов [7, 8]. На территории автономной республики отмечается закономерное распределение минеральных источников, большинство которых относятся по составу к углекислым гидрокарбонатным, магниево-кальциевым по составу с широким спектром лечебных свойств.

Материалы и методы

Объектами исследования являются минеральные, термальные, кягризные и артезианские воды Нахчыванской Автономной Республики. Отбор проб подземных вод проводился авторами во время полевых маршрутов в 2022-2025 год в составе научной экспедиции, организованной лабораторией «Гидрогеология и минеральных вод». На месте проб отбора измерялись параметры быстроменяющихся компонентов: температура, удельная электропроводность, Eh, pH при помощи анализатора Water Test Hanna instruments. Вода для анализа макро- компонентного состава отбиралась в пластиковую посуду объемом 2 л. Концентрации Cl^-, SO_4^{2-} Ca^{2+}, Mg^{2+}, Na^+, K^+ были определены методом ионной хроматографии (ICS 1000), концентрации HCO_3^- определялись методом титрования раствором (0,1 моль) HCl, концентрации кремния атомно-абсорбционной спектрометрией [9,10]. Для всех образцов воды определена степень минерализации, жесткость, количество ионов магния, кальция, сумма натрия и калия, гидрокарбонатов, хлоридов, сульфатов и pH среды. Концентрация указанных компонентов в воде выражена в мг-экв/л и мг/л. Современные методы анализа учитывают наличие

элементов, присутствующих в воде в количестве от 10^5 до 10^7 г/л или менее. В это время некоторая часть анализов проводятся непосредственно на станциях водоснабжения (реки, родники, минеральные источники), с помощью подвижных полевых лабораторий, а остальная часть в лабораториях на базе гидрогеохимических партий.

Обсуждение результатов

Оценка опасности загрязнения проводится с использованием индексов опасности загрязнения как одной из характеристик устойчивости окружающей среды к негативному воздействию [11,12]. Для каждой группы загрязняющих веществ рассчитывался групповой индекс опасности загрязнения по предложенному нами выражению. В данной работе рассматриваются подходы, методы изучения пресных подземных вол, родников, кягризов, минеральных и термальных источников, приводятся гидрологические и гидрохимические характеристики современного их состояния. Интенсивное образование подземных вод в автономной республики, обусловлено наличием сложных гидрогеологических условий в этом регионе. Генезис полезных ископаемых в Нахчыванской Автономной Республике, в которой имеются различные источники минеральных вод, объем, а также состав водного слоя в разных геологических периодах, сыграли решающую роль в образовании минеральных вод и формировании микроэлементных составов.

На площади 900 км^2 в Джульфинском районе были обнаружены 85 источников минеральных вод, 42 из которых выходят на поверхность земли через буровые скважины. Минеральные источники распределяются следующим образом: Дарыдаг-37, Нахаджир-10, Лекетаг-5, Казанчи-2, Башканд-2, Агсал-2, Неви-2, Дерешам-2, Тейваз-2, Хошкешин-1, Гюлистан-1. Дарыдагский минеральный источник относится к высокотемпературным мышьяковым, сурьмяным водам. Эти элементы определяют основные лечебные свойства Дарыдага. Кроме того, в минеральных источниках было обнаружено небольшое количество висмута, элемента подгруппы мышьяка, который ассоциируется с мышьяком и сурьмой в минеральных водах. Воды, с содержанием висмута, были обнаружены в Джульфинском районе, в Дарыдаге и, прилегающей к нему местности, Каримгулу-Дизе. В водах обоих термальных месторождений, наряду с элементами подгруппы мышьяка также содержится и бор. Количество бора при расчете на B_2O_3, в термальном источнике Дарыдаг колеблется в пределах 800-850 мг/л. Ниже приведены сравнительные характеристики химических составов и физико-химические особенности подземных вод различных источников Джульфинского района районов.

Таблица 1.

Физико-химические показатели некоторых источников Джульфинского района

Название источника	Химический состав	T, ^{0}C	M,мг/л	pH	D m^3/день
Башкенд	CO_2 1,5 $\frac{HCO_3 85\ SO_4\ 11}{Ca\ 49\ (Na+K)26Mg25}$	16	2,0	7,3	16
Дарыдаг	As 22mг/л CO_2 0,8 $\frac{HCO_3 29\ Cl\ 64}{(Na+K)93}$	50	22,0	6,6	4507
Дерелик	CO_2 1,3 $\frac{HCO_3 72\ \ Cl18}{Ca\ 37\ Mg\ 25(Na+K)38}$	20	3,6	6,4	150
Дерешам	CO_2 1,3 $\frac{HCO_3 62\ SO420\ Cl19}{Ca\ 47\ Mg\ 29(Na+K)24}$	22	2,5	6,6	200
Динге	CO_2 0,7 $\frac{HCO_3 72\ SO425}{Mg39Ca\ 33\ (Na+K)28}$	17	1,2	6,3	15
Арафса	CO_2 1,3 $\frac{HCO_3 87}{(Na+K)58\ Ca\ 22\ Mg\ 21}$	14,5	4,3	6,3	25
Гюлустан	CO_2 2,0 $\frac{HCO_3 71\ Cl16}{(Na+K)38\ Ca\ 37\ Mg\ 25}$	21`	3,4	6,4	250
Гави	CO_2 1,7 $\frac{HCO_3 79\ c}{Ca\ 42\ (Na+K)38Mg18}$	12	2,0	6,6	70
Хошкешин	CO_2 2,0 $\frac{HCO_3 71\ Cl16}{(Na+K)38\ Ca\ 37\ Mg\ 25}$	25	8,6	6,4	35
Газанчы	CO_2 1,5 $\frac{HCO_3 71\ \ SO_4\ \ 20}{(Na+K)38\ Ca\ 36\ Mg\ 27}$	19	4,5	6,4	15
Лекетаг	CO_2 1,5 $\frac{HCO_3 71\ \ SO_4\ \ 20}{(Na+K)38\ Ca\ 36\ Mg\ 27}$	17	1,7	6,7	400

Комплексное исследование источников минеральных вод на территории автономной республики, позволяет с одной стороны провести их классификацию, а с другой сравнительную характеристику по районам.

Оценка опасности загрязнения проводится с использованием индексов опасности загрязнения как одной из характеристик устойчивости окружающей среды к негативному воздействию. Для каждой

группы загрязняющих веществ рассчитывался групповой индекс опасности загрязнения по предложенному нами выражению (табл.2, рис.1)

Таблица 2.

Характеристика загрязнения подземных вод в автономной республике (по А.П. Белоусовой)

Типы вод	Суммарного коэффициента загрязнения	Ассоциация элементов	Категория загрязнения
Родниковые воды	4,92	Na+K, Ca, Mg, HCO_3,Cl, SO_4	Слабо загрязненная
Кягризные воды	0,8	Ca, Mg, Na+K, HCO_3,Cl, SO_4	условна чистая
Минеральные воды	1,02	Ca, Mg, Na+K, SO_4, HCO_3,Cl, Y,B,CO_2	условна чистая
Артезианские воды	1,70	Ca, Mg, Na+K, HCO_3, Cl, SO_4, Fe	условна чистая
Коллекторно-дренажные воды	5,40	Na+K, Ca, Mg, HCO_3,Cl, SO_4, B, Fe, Al	Слабо загрязненная

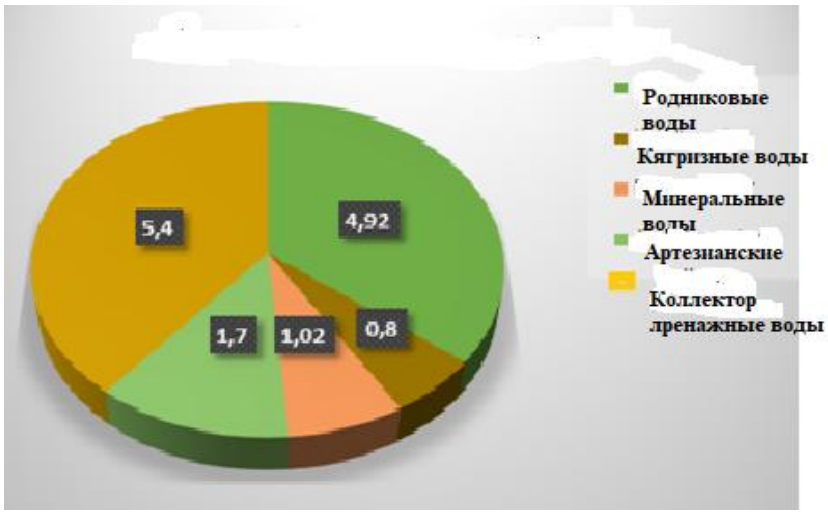

Рисунок 1. Диаграмма оценки коэффициентов загрязнения подземных вод

На основании полученных результатов, за исключением нескольких, показано пригодность использования большинства изученных вод для питья и технических нужд населения. Как видно из таблиц, воды от очень мягких до умеренно жестких, среда нейтральная, либо слабощелочная. За весь период наблюдений содержание сухого остатка в подземных водах водоносного комплекса не превышало предельно допустимых концентраций. Исходя из этого, можно предположить дальнейшее стабильное содержание данного показателя в подземных водах автономной республике.

Таблица 3.

Распределение загрязняющих веществ по территории автономной республики

	Загрязняющие вещества				
Районы	**Сульфаты, хлориды**	**Соединения азота**	**Нефтепродукты**	**Фенолы**	**Тяжелые металлы**
Бабек	5	12	–	–	4
Кенгерли	5	14	–	–	5
Джульфа	6	10	–	–	4
Ордубад	7	5	–	–	6
Шахбуз	4	4	–	–	4
Шарур	8	8		–	4
Садарак	6	7	–	–	3
Итого	41	60	–	–	30

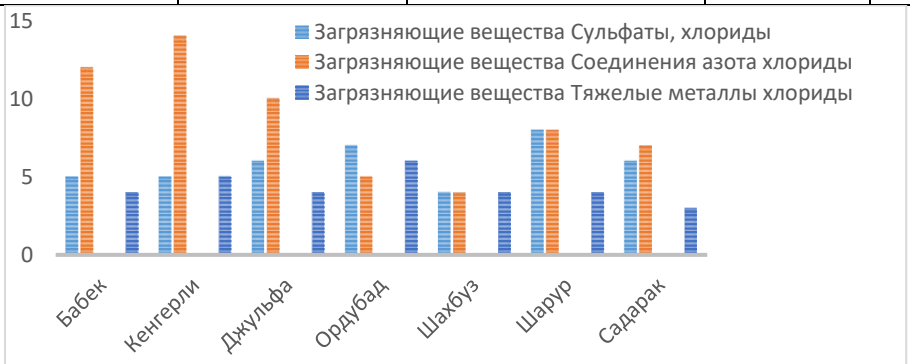

Рисунок 2. Распределение загрязняющих веществ по территории автономной республики

Как видно из таблицы и диаграмм в автономном республике нет сильное опасности загрязнения подземных вод опасными химическими загрязнителями.

Пригодность воды для посевных площадей служит улучшению продуктивности и питания с точки зрения контроля над последними мелиоративными нормами [11,12[. Производство экологически чистой пищевой продукции в первую очередь зависит от соблюдения мелиоративных правил, правильного использования природных удобрений и водных ресурсов для орошения. Распределение кягризных вод по территории автономной республики приведено на рис.3.

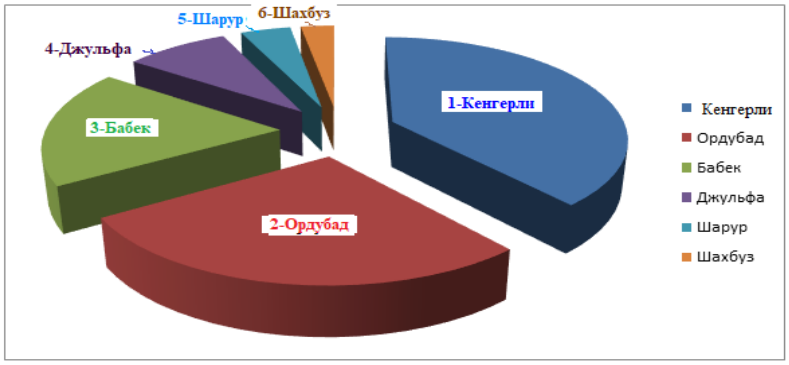

Рисунок 3. Распределение кягризов по территории автономной республике: 1-Кенгерли, 2-Ордубад,3-Бабек, 4-Джульфа, 5-Шарур, 6-Шахбуз

Согласно этой классификации, в Кенгерлинском районе зарегистрировано 142 кягриза и родников. Так как на территории этого района отсутствует речная сеть, в орошении посевных площадей широко используются воды кягризных, родниковых, а также субартезианских скважин. В Кенгерлинском районе имеется запас подземных вод 75,1 млн.м^3. Кроме того, учитывая, что годовой объем родника “Асны” в верхней части территории, составлет 20-25 млн.м^3, можно отметить, что запасы воды этой территории около 100 млн., м^3. Неповторимый вкус и качество выращенной на территории Нахчыванской Автономной Республики сельскохозяйственной продукции и фруктов - бесценное достояние земли, воды и воздуха этого прекрасного края одаренного людям. Научные исследования этих источников воды, которые служат людям веками, подтверждают, что подземные воды, природные богатства океана, кипящие под ногами, в виде кягризов, родников и чешме выходят на поверхность Земли, вынося с собой все полезные элементы окружающих пород. Невозможно не удивляться этим чудесным источникам воды и с почтением вспомнить кэн-кэнов, которые с таким трудом вынесли эту чистую, прозрачную как хрусталь воду и дали нам в распоряжение. Давайте совершим экскурсию для сравнения химических экологических особенностей отдельных образцов кягризных систем в Нахчыванской Автономной республике.

Таблица 4.

Техническое состояние кягризов и водопотребление в районах

Районы	**Качество ранее существующих кягризов**	**Количество Доступных кягризов**	**Предыдущий расход воды, л/с**	**Текущий расход воды, л/с**
Кенгерли	181	142	1325,7	573,1
Бабек	80	39	831,0	536,0
Ордубад	93	108	553,5	399,7
Джульфа	30	38	617,5	272,5
Шахбуз	8	5	55,0	86,5
Шарур	15	9	14,7	70

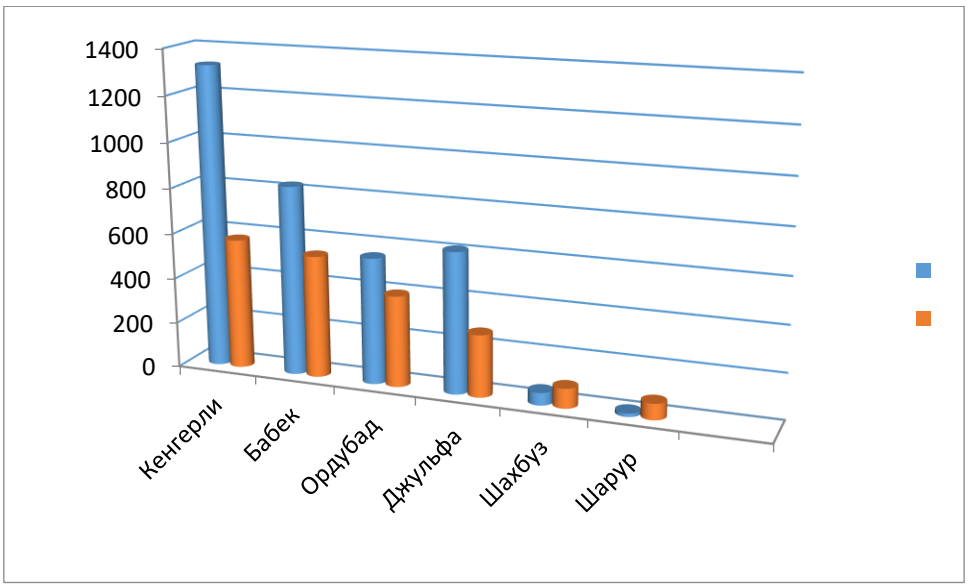

Рисунок 4. Сравнительная схема водопотребления кягризов по районам:
предыдущий расход воды, л/ с ; текущий расход воды, л/с

Как видно из таблицы, фактическое потребление кягризные воды в автономной республике составляет 2191,7 л/с, т.е. на 1733,7 л/с или на 44,16 % меньше, чем в предыдущем 3925,4 л/с. Анализ показал, что эта разница уменьшится после восстановления потребления воды в кягризах, нуждающихся в ремонте. Для повышения эффективности использования кягризных систем в Автономной Республике, необходимо учитывать их потенциальные возможности и усилить работу по охране и восстановлению этих уникальных гидротехнических сооружений. Следуя нормам и режимам их использования, нужно осуществлять меры по предотвращению экомелиоративных нарушений.

Таким образом, загрязнение подземных вод тесно связано с загрязнением окружающей среды в целом. Практически невозможно предотвратить загрязнение подземных вод при продолжающемся загрязнении атмосферы, поверхностных вод, почв. Охрана подземных вод от загрязнения окружающей природной средой должна осуществляться в рамках этой общей проблемы. Меры по защите подземных вод должны быть увязаны не только с общими вод охранными мероприятиями, но и с мероприятиями по охране от загрязнения природной среды в целом [13, 14]. В противном случае специальные меры по защите подземных вод могут оказаться неэффективными. Это важное принципиальное положение должно быть положено в основу охраны подземных вод и планирования, соответствующих мер водоохраны.

Результаты анализа показывают, что в последние годы эко-химическое состояние подземных вод в автономной республике относительно стабильно по сравнению с поверхностными водами и значительного загрязнения не наблюдается. В настоящее время отдельные реки, озера, минеральные, кягризные и артезианские источники рассматриваются как объекты, имеющие статус особо охраняемых природных территорий. Следовательно, особо ценные водные объекты могут иметь не только рекреационную значимость, но и представлять просветительскую и образовательную ценность как участки особой охраны. Совокупность приведенных материалов дает нам возможность предложить ряд практических рекомендаций по рациональному использованию водных ресурсов автономной республики.

Литература

1. Аббасов А.Д., Мамедова Ф., Гурбанов Г. Экология и окружающая среда во взаимоотношении общества и природы. Нахчыван, «Аджеми», 2018, 290 с.

2. Мамедова Ф.С., Аббасов А.Д. Ресурсы подземных вод Нахчыванской

Автономной Республики и их химико-экологические особенности //Наука России: Цели и задачи. Екатернбург, Часть 4, 2019, с. 9-16.

3. Байрамова Л.А., Сеидов И.В. Экологические аспекты охраны ресурсов подземных вод в Нахчыванской АР // Символ Науки, 2016, №5, с.27-30.

4. Захарова И.К. Оценка качества родниковой воды села Лазарево Владимирской области // Международный научный журнал «Инновационная наука».2011, №12, с. 73-76

5. Белоусова А.П., Гавич И.К., Лисенков А.Б., Попов Е.В. Экологическая гидрогеология. Москва, Академкнига, 2006, 397 стр.,

6. Мамедова А. Динамика подземных вод. Баку, 2012, 206 с.
7. Назаров А.А. Долголетие без болезней. Минеральные воды на страже здоровья. М.: Открытое Решение, 2008, 152 с.
8. Левчук А.А., Барабаш А.Ю., Александрова А.В., Левчук А.А. Аспекты управления экологической безопасностью в водохозяйственном комплексе / А.А. Левчук [и др.] // Вестник Евразийской науки. – 2018. – № 2. – Режим доступа: https://esj.today/PDF/44NZVN218.pdf.
9. Пономарева В.Д., Иванов Л.И. Практикум по аналитической химии. М.: Высшая Школа, 1983, 271с.
10. Фритц Дж., Щенк Г. Количественный анализ. М.: Мир, 1978, 557 с.
11. Тавасиев В.Х. Рациональное использование подземных пресных вод в Республике Северная Осетия- Алания. // Успехи современного естествознания. 2015. № 12. С. 169-172; URL: https://natural-sciences.ru/ru/article/view?id=35768
12. Васильченко О.В. Гидроэкология: особенности оценки качества вод // Инженерная экология.2003, №3, с.2-25.
13. Шварцев, С. Л. **Вода как главный фактор глобальной эволюции** // Вестник Российской академии наук, 2013, Т. 83, № 2, С. 124–131
14. Язвин Л.С. Оценка прогнозных ресурсов питьевых подземных вод и обеспеченность населения России подземными водами хозяйственно-питьевого назначения // Разведка и охрана недр. 2003, № 10, с.13–19.

SUPRAMOLECULAR COMPOUNDS OF POLYOXOMETALATES IN THE ANALYSIS OF HUMIC ACIDS

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Fulvic acids (FA) are natural high-molecular compounds formed as a result of humification of organic residues. They are representatives of humus compounds with antioxidant, chelating and biologically active properties. These characteristics determine the use of fulvic acids in various industries:

- agricultural sector - a substance that stimulates plant growth and increases stress resistance to adverse environmental conditions, improves soil structure, restores their fertility, reduces the need for chemical fertilizers, increases the absorption of nutrients;
- veterinary medicine and animal husbandry - a natural bioregulator that has a positive effect on the immune system of animals, improves feed digestion and promotes the elimination of toxins; allows you to reduce the use of antibiotics and growth stimulants;
- medicine and pharmacy - a component of food bioactive additives for antioxidant protection, removal of heavy metals, normalization of intestinal microflora and enhancement of the action of other biologically active substances;
- ecology - water purification from heavy metals and organic pollutants, as well as in filtration systems.

Fulvic acids play a key role in soil formation, affect the bioavailability of minerals and toxicants, and participate in the transport of metals and bioactive compounds. However, their analysis remains challenging due to their heterogeneous structure, tendency to complex formation, and lack of unified standards.

To separate fulvic acids from other humus acids, a mineral acid, usually HCl, is added to an aqueous or alkaline soil extract to a pH of ≈ 1 to precipitate the humus acids [1]. To determine the presence of humus substances, reactions with iron (III) salts [2] are used, with reactions with silver nitrate or zinc sulfate, which allow the separation of fulvic acids from humus acids [3]. Fluorescence tests are sometimes also used, since solutions of fulvic acids, especially in alkaline media, often have a yellowish or greenish glow under UV irradiation, which is associated with their aromatic structure [4].

Today, the most common methods for quantitative analysis of fulvic acids are alkalimetric and acidimetric methods with determination of the total number of functional carboxyl and phenolic groups, reactions with bromine or iodine, which allow to determine the degree of unsaturation of the compound [5], spectrophotometric methods, which allow to estimate the degree of polymerization [6]; high-performance liquid chromatography method, which allows to study in more detail the composition of fulvic acid fractions, to identify individual components [7].

Existing methods often require lengthy sample preparation, do not provide sufficient selectivity for fulvic acids in the presence of other organic substances, and do not allow for control of low concentrations in complex matrices. Therefore, the development of new, more efficient approaches to the analysis of fulvic acids is of great scientific and practical importance.

In modern analytical chemistry, methods that combine high accuracy, sensitivity and selectivity with the ability to study complex natural objects without complex pre-treatment are in demand. One of the promising areas of development of such methods is the use of supramolecular systems - compounds capable of selective recognition of analytes due to weak non-covalent interactions. Supramolecular chemistry, which was formed at the interface of organic, coordination and physical chemistry, opens up new opportunities in the development of sensor systems. In this context, the use of sensors based on supramolecular substances that

were specially synthesized for selective interaction with fulvic acids is promising. Such sensors can provide not only qualitative recognition, but also quantitative determination of fulvic acids using electrochemical, optical or other physicochemical signals.

As the second component for obtaining a supramolecular substance based on fulvic acids, we proposed the use of polyoxometalates. Polyoxometalates (POM) are representatives of polyligand inorganic substances, which can be attributed to coordination inorganic polymers, since the POM macromolecule includes groups of atoms of different symmetries, forming structurally complex particles characterized by overall high symmetry [8-9].

To determine the possibility of obtaining a new supramolecular compound, the type of bond in the obtained compound and the rational conditions for the reaction were investigated by UV spectrophotometric method. For this purpose, the spectral characteristics of fulvic acid solutions were previously recorded at the inherent acidity of the solution pH = 4.0 and in the acidic region (pH < 4), since their precipitation occurs when fulvic acid solutions are alkalized. According to the results of the study, it was found that in fulvic acid solutions, regardless of pH, a high-intensity absorption maximum is observed at 200 nm, a shoulder and a maximum of medium intensity at 215-225 nm and 260 nm, a shoulder and a maximum of weak intensity at 305-320 nm and 335 nm.

Molybdenum polyoxometalates are characterized by intense absorption in the UV region of the spectrum [8-9]. The highest energy absorption band for POM is located in the region of 200-220 nm, which is related to charge transfer along the terminal Me-O bonds. The following bands at 240-250 nm and 330 nm for molybdenum POM characterize charge transfer in linear and angular bridge bonds Me←O→Me.

Previous studies of anionic and nonionic compounds with a large number of hydroxyl and carboxyl groups - for example, polysorbates [10] indicate the possibility of obtaining supramolecular substances based on anionic and nonionic organic substances and polyoxometalates using barium salts. Therefore, in order to study the possibility of obtaining supramolecular substances of fulvic acids with molybdenum polyoxometalates, cationic complexes with barium salts were previously obtained and studied depending on the acidity of the studied solution. The obtained experimental data indicate that in complexes of fulvic acids and barium salts there is an absorption maximum at 200 nm; a shoulder at 230-240 nm, absorption maxima at 255 nm, 320 and 345 nm.

The properties of supramolecular substances FA-Ba-POM depending on the pH of the studied solution were also investigated by UV spectroscopic method. It was found that at pH = 2.0 in the spectral characteristics of the obtained supramolecular substance FA-Ba-POM, absorption maxima are observed at 200 and 330 nm, a shoulder at 215-220, 230-235, 255-260, 310-320 nm. For the supramolecular substance FA-Ba-POM at pH = 4.0, absorption maxima are observed at 200, 210, 345 nm and a shoulder at 225-235, 255-260, 310-320.

Comparison of the spectral characteristics of the starting substances and the obtained supramolecular substance FA-Ba-POM indicates the preservation of the absorption bands of the starting substances in the total absorption spectrum of the obtained product, as well as a significant increase in absorption, which indicates the preparation of a compound with an ionic-associative bond nature, and therefore the presence of electroactive properties in the obtained supramolecular substances.

References

1. Orlov, D. S. Gumusovyie kislotyi i obschaya teoriya gumusa. MGU, 1995, 324 p.

2. Stevenson, F. J. Humus chemistry: genesis, composition, reactions. Wiley, 1994, 496 p.

3. Tan, K. H. Humic Matter in Soil and the Environment: Principles and Controversies / K. H. Tan, CRC Press, 2014, 495 p.

4. Sun, X. L. Optical Properties of the Suwannee River Fulvic Acid Complexation with Thorium Using 3D Fluorescence Spectroscopy. X. L. Sun, X. Ma, L. Leng, Y. Fang, Spectroscopy, 2022: 26-33.

5. Schnitzer, M. Humic Substances in the Environment / M.Schnitzer, S. U. Khan, M. Dekker. 1972. 745–754 p.

6. Senesi, N. The chemistry of soil organic matter / N. Senesi, E. Loffredo // *Soil Chemistry.* Springer, 2003: 165-174.

7. Nebbioso, A. Molecular characterization of dissolved organic matter (DOM): a critical review / A. Nebbioso, A. Piccolo // Analytica Chimica Acta, 2013: 109-124.

8. Talismanov, S. S. Himicheskoe konstruirovanie gomo- i geteroyadernyih polioksomolibdatnyih klasterov / S. S. Talismanov, I. L. Eremenko // Uspehi himii, 2003, 72 (7): 627-642.

9. Tkach, V. I. Vykorystannia heteropolianioniv struktury Kehhina v analizi orhanichnykh ta neorhanichnykh spoluk / V. I. Tkach, N. I. Karandieieva, L. P. Tsyhanok, A. B. Vyshnikin / Monohrafiia. - Dnipropetrovsk: UDHTU, 2002, 184 p.

10. Mironyak, M. O. Study of the reaction of polysorbate-20 with heteropolyacids of the Keggin structure by the photometric method / M. O. Mironyak, O. V. Volnyanska, M. V. Manzuk, O. V. Labyak, M. V. Nikolenko, V. L. Kovalenko, V. A. Kotok // ARPN Journal of Engineering and Applied Sciences, 2020, 15 (8): 998–100.

Jurisprudence

POWERS AND PROCEDURE OF THE PROSECUTOR'S OFFICE IN THE INTERNATIONAL CRIMINAL COURT

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Abstract

This article analyzes the legal status, powers and mechanisms of action of the Prosecutor's Office in the International Criminal Court (ICC). The study explains the role of the Prosecutor's Office as an independent institution based on the Rome Statute and examines its functions in investigating the most serious crimes of international law - genocide, crimes against humanity, war crimes and crimes of aggression. The article also systematically presents the main stages of the investigative process of the Prosecutor's Office, the procedures of preliminary investigation, formal investigation and trial. Special attention is paid to the principle of independence of the Prosecutor's Office and its activities free from political influence. As a result, it is concluded that the ICC Prosecutor's Office acts as an important guarantee mechanism in international criminal justice and plays an indispensable role in the protection of human rights.

Keywords: International Criminal Court, powers of the prosecutor's office, international crimes, Rome Statute, criminal prosecution.

Introduction

In the contemporary system of international law, preventing impunity for the gravest crimes constitutes a fundamental prerequisite for the realization of global justice. To this end, the International Criminal Court (ICC) was established as the principal international judicial institution entrusted with ensuring individual criminal responsibility for acts regarded as the most serious crimes of concern to the international community, including genocide, crimes against humanity, war crimes, and the crime of aggression.

The effective functioning of the ICC is directly contingent upon the powers and properly structured operational mechanisms of one of its core organs—the Office of the Prosecutor. This article undertakes a comprehensive analysis of the legal status, scope of authority, and procedural framework governing the Office of the Prosecutor, while examining the role of this institutional mechanism in the progressive development of international criminal law.

Main Body

Pursuant to Article 42 of the Rome Statute, the Office of the Prosecutor of the International Criminal Court is established as an independent organ. Such independence enables the Prosecutor to perform his or her functions without being subject to political direction or interference from any State or international organization [7]. The primary mandate of the Prosecutor consists in investigating crimes that pose a particular threat to the international community and in prosecuting individuals responsible for their commission.

Unlike traditional domestic prosecutorial authorities, the Office of the Prosecutor of the ICC exercises jurisdiction exclusively over natural persons. It does not assert jurisdiction over States but instead ensures the individual criminal responsibility of specific persons [3]. This distinctive feature is widely regarded as a significant milestone in the evolution of international criminal law.

The core competencies of the Office of the Prosecutor encompass the gravest crimes under international law, namely genocide, crimes against humanity, war crimes, and the crime of aggression [6]. The Prosecutor may receive information concerning such crimes from States, the United Nations Security Council, and individual natural persons.

In the course of an investigation, the Prosecutor is vested with broad powers, including the collection of evidence, the examination of witnesses, the obtaining of expert opinions, the review of documentary materials, and the conduct of on-site inspections [1]. In addition, the Office of the Prosecutor engages in cooperation with States through established mechanisms of international legal assistance. Such cooperation covers, inter alia, extradition, witness protection, and the exchange of evidentiary materials.

A significant procedural stage in the activities of the Office of the Prosecutor is the preliminary examination. At this stage, the Prosecutor assesses whether the situation falls within the jurisdiction of the Court, evaluates the gravity of the alleged crimes, and determines whether national jurisdictions have undertaken genuine and effective investigations or prosecutions in respect of the matter concerned [2].

At this stage, the principal legal mechanism is the principle of complementarity. Under this principle, the ICC intervenes only where States are unwilling or genuinely unable to carry out effective investigations or prosecutions [3]. This mechanism serves to preserve the balance between national sovereignty and the imperatives of international justice. Following the preliminary examination, where a reasonable basis exists, the Prosecutor seeks authorization from the Pre-Trial Chamber to initiate a formal investigation. During this phase, the evidence collected is systematized and subjected to comprehensive legal analysis. The Prosecutor then prepares the indictment and submits it to the judges [7].

At the stage of confirmation of charges, the judges assess whether the evidence presented by the Prosecutor is sufficient to establish substantial grounds to believe that the accused committed the alleged crimes. If the charges are confirmed, the case is referred to the Trial Chamber, where the Office of the Prosecutor appears as the prosecuting authority. This stage is of particular significance in ensuring the guarantees of a fair trial within the framework of international criminal proceedings.

One of the fundamental principles underpinning the activities of the Office of the Prosecutor is independence. The Prosecutor must operate free from political, military, or diplomatic pressure and base decisions exclusively on legal considerations and evidentiary standards. This institutional safeguard reinforces the legitimacy of the ICC and enhances international confidence in its determinations.

In addition, the Prosecutor is bound by the principle of objectivity. Accordingly, during the investigative phase, the Prosecutor is obligated not only to collect and present incriminating evidence but also to seek and disclose exonerating evidence (Rules of Procedure and Evidence, ICC). Notwithstanding its institutional mandate, the Office of the Prosecutor faces a number of significant challenges. One of the most pressing difficulties concerns the refusal of certain States to cooperate. The failure of States to execute arrest warrants or to provide requested evidence adversely affects the effectiveness and timeliness of investigations.

Another major challenge arises from political dynamics and broader international relations considerations. In particular, during armed conflicts, the Prosecutor's access to crime scenes and relevant territories may be severely restricted. Despite these constraints, the Office of the Prosecutor continues to operate as a central institutional mechanism for the enforcement of international criminal justice.As one of the independent and pivotal organs of the International Criminal Court, the Office of the Prosecutor bears responsibility for the investigation and prosecution of international crimes. Its jurisdiction extends to genocide, crimes against humanity, war crimes, and the crime of aggression. The activities of the Office are grounded in the Rome Statute and are carried out in strict accordance with the principle of full institutional independence.

An analysis of the reporting period indicates that the operational framework of the Office of the Prosecutor is generally structured into four principal stages: preliminary examination, investigation, preparation of charges, and participation in the trial phase. This phased structure facilitates the systematic conduct of proceedings and ensures the effective collection and organization of evidence. The Office of the Prosecutor actively cooperates with national authorities, United Nations bodies, and international human rights organizations. According to the findings of the report, international cooperation plays a decisive role in expediting investigative processes. In particular, mechanisms related to evidence gathering and witness protection are identified as key factors enhancing the overall effectiveness of the Office. The overall assessment demonstrates that the activities of the Office of the Prosecutor make a substantial contribution to the strengthening of international criminal justice, the fight against impunity, and the protection of fundamental human rights [8].

Table 1.

Principal Powers of the Office of the Prosecutor of the ICC

Area of Authority	Content	Practical Significance
Preliminary Examination	Collection and assessment of information	Identification of indicia of criminal conduct
Conducting Investigations	Gathering of evidence; questioning of witnesses	Preparation of the case for judicial proceedings
Bringing Charges	Drafting and submission of formal indictments	Ensuring the prosecution and accountability of accused persons
International Cooperation	Engagement in legal assistance mechanisms with States	Securing evidence and obtaining custody of individuals
Witness Protection	Implementation of security and confidentiality measures	Encouraging witness participation and safeguarding testimony

The allocation of resources and workload across the principal areas of activity of the Office of the Prosecutor of the International Criminal Court may be provisionally structured as follows. Preliminary examinations account for approximately 25% of overall activity. At this stage, the Office collects and evaluates incoming information in order to determine whether there are reasonable grounds to believe that crimes within the jurisdiction of the Court may have been committed. This phase serves as the foundational stage for case initiation and strategic planning. Investigative activities constitute the largest proportion, approximately 35% of

the Office's work. During this phase, evidence is gathered, witnesses are interviewed, and case files are prepared to meet the evidentiary standards required for judicial proceedings. International cooperation represents approximately 20% of operational efforts. Within this framework, the Office engages with States, United Nations bodies, and other international organizations to secure evidence, obtain access to witnesses, and facilitate other forms of legal assistance. Such cooperation significantly enhances the effectiveness and efficiency of investigations. Participation in judicial proceedings comprises approximately 15% of activities. In this capacity, the Prosecutor presents the case before the Court, submits evidence, examines witnesses, and actively participates in trial hearings. Finally, witness protection measures account for roughly 5% of institutional efforts. These measures are aimed at ensuring the safety and confidentiality of witnesses and encouraging their willingness to provide testimony [9].

These proportions demonstrate that the primary focus of the Office of the Prosecutor lies in investigative activities and preliminary examinations, which together constitute the core of its operational mandate. International cooperation and participation in judicial proceedings serve complementary functions, facilitating the completion and procedural advancement of cases. Although witness protection accounts for a comparatively smaller percentage of overall activity, it remains of critical importance. The effectiveness of investigative and prosecutorial efforts is intrinsically linked to the security, confidentiality, and reliability of witness testimony, rendering this function strategically indispensable within the broader framework of international criminal justice.

Conclusion and Recommendations

The analysis conducted demonstrates that the Office of the Prosecutor of the International Criminal Court constitutes one of the central actors within the system of international criminal justice. Its broad mandate, independent legal status, and structured, multi-stage investigative mechanism make a substantial contribution to the effective enforcement of international criminal law. The jurisdictional framework established by the Rome Statute enables the Office to investigate and prosecute genocide, crimes against humanity, war crimes, and the crime of aggression. At the same time, practice indicates that deficiencies in inter-State cooperation mechanisms, as well as political considerations, create tangible obstacles to the effective functioning of the Office. Limitations in the execution of arrest warrants, restricted access to evidence, and geopolitical constraints may undermine the efficiency and timeliness of proceedings. Overall, the Office of the Prosecutor serves as a vital legal mechanism in the global fight against impunity and plays a decisive role in strengthening accountability at the international level. Strengthening cooperation frameworks, enhancing compliance mechanisms, and reinforcing institutional safeguards for prosecutorial independence remain essential for further consolidating the effectiveness of the ICC system.

Further strengthening cooperation mechanisms between national judicial systems and the International Criminal Court is of paramount importance. Encouraging broader accession of States to the Rome Statute may contribute positively to the expansion of the Court's jurisdiction and enhance the operational capacity of the Office of the Prosecutor. At the same time, it is advisable to improve witness protection systems and to expand technological capabilities in the field of evidence collection and preservation, including digital forensics and secure data management. Such measures would significantly increase the efficiency and reliability of prosecutorial activities. Moreover, safeguarding the institutional independence of the Office of the Prosecutor and ensuring the allocation of adequate financial resources are essential preconditions for the effective functioning of the international criminal justice mechanism. Strengthened institutional resilience and sustainable funding structures would further reinforce the capacity of the ICC to combat impunity and uphold the rule of law at the international level.

References

1. Ambos, K. (2010). The powers of the ICC prosecutor. Criminal Law Forum, 21(3), 453–465.
2. Cassese, A. (2013). International criminal law (3rd ed.). Oxford University Press.
3. Cryer, R., Friman, H., Robinson, D., & Wilmshurst, E. (2019). An introduction to international criminal law and procedure (4th ed.). Cambridge University Press.
4. International Criminal Court. (2011). Rules of procedure and evidence. International Criminal Court.
5. Moreno-Ocampo, L. (2007). The role of the ICC prosecutor. Journal of International Criminal Justice, 5(2), 395–406.
6. Rome Statute of the International Criminal Court. (1998). United Nations.
7. Schabas, W. A. (2017). An introduction to the International Criminal Court (5th ed.). Cambridge University Press.
8. https://www.icc-cpi.int/sites/default/files/2024-05/Rome-Statute-eng.pdf
9. https://thelaw.institute/application-of-ihl/international-criminal-court-key-features-global-justice/

Medical sciences

THE ROLE OF ARTIFICIAL INTELLIGENCE IN SELECTING NEW TREATMENT METHODS

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Relevance. The relevance of our day is the development and preparation of new treatment methods in any field of medicine, as well as in such inseparable departments as pharmacy and physiotherapy.The medical field is a field that is constantly evolving and improving with the integration of new technologies. The application of modern approaches to protect human health and achieve high efficiency in the treatment of diseases is one of the main goals of doctors and researchers. Modern algorithms, such as deep neural networks (DNNs) and convolutional neural networks (CNNs), significantly increase the accuracy and speed of disease diagnosis by analyzing medical images such as X-ray, MRI, CT, and electron microscopy (EM). This not only improves the quality of medical services, but also contributes to the development of new treatment and prevention methods.[1],[2] In medical diagnostics, AI helps detect diseases such as cancer at an early stage through mammography, CT and MRI analyses. Algorithms can detect small tumors and abnormalities that may be missed by humans. Electron microscopy provides detailed images of cell and tissue structures at high resolution in medical diagnostics. AI can be used to accurately identify viruses, bacteria and cellular abnormalities by analyzing electron microscopy images. This is especially important in the investigation and treatment of infectious diseases. So, first of all, let us emphasize that medical robots equipped with artificial intelligence increase the accuracy of surgical operations: During microinvasive operations, robots can move with high precision and intervene without damaging tissues.[3] - It becomes easier to manage surgical processes and optimize results [4]. - The application of artificial intelligence in medicine has led to significant changes in the field of healthcare in recent years. However, the large-scale application of this technology faces a number of difficulties. The main difficulties are related to technological, ethical, legal and social issues. First of all, the quality and accessibility of medical data are essential for the proper functioning of artificial intelligence. However, as a result of the diversity, incompleteness and inaccuracy of medical data, algorithms can give incorrect results.[5]

Aim to study. The main goal was to investigate the advantages and disadvantages of applying artificial intelligence in medicine. At the same time, it is to find ways to use new methods in the field of physiotherapy and rehabilitation for therapeutic purposes.

Materials and methods. A comprehensive literature search was conducted across 8 databases: OVID MEDLINE, OVID Embase, OVID PsycINFO, EBSCO CINAHL Plus with Full Text, ProQuest Sociological Abstracts, ProQuest Philosopher's Index, ProQuest Advanced Technologies & Aerospace, and Wiley Cochrane Library.

Results. However, persistent concerns remain, including biases ingrained in AI algorithms, a lack of transparency in decision-making, potential compromises of patient data privacy, and safety risks associated with AI implementation in clinical settings.

Conclusion. Based on all the information, we can say that although some shortcomings of the method can be identified, the application of artificial intelligence in modern medicine is of great importance for more accurate diagnosis.

References

1. McCarthy J. (2024) What is artificial intelligence? URL: https://wwwformal.stanford.edu/jmc/whatisai.pdf
2. Srivastava R. (2023) Applications of artificial intelligence in medicine. Explor Res Hypothesis Med. Published online: Sep. 19. https://doi.org/10.14218/ERHM.2023.00048.
3. Алексеева М.Г., Зубов А.И., Новиков М.Ю. (2022) Искусственный интеллект в медицине. Международный научно-исследовательский журнал.; 7: 10-3. https://doi.org/10.23670/IRJ.2022.121.7.038.
4. Szegedy C., Vanhoucke V., Ioffe S., Shlens J. (2021) Rethinking the Inception Architecture for Computer Vision. arXiv preprint: arXiv:1512.00567v3, 2015. URL: https://arxiv.org/pdf/1512.00567v3.pdf (дата обращения 06.10.2021)

5. Jimma B.L. (2023) Artificial intelligence in healthcare: a bibliometric analysis. Telemat Inform Rep

UDC: 616-006.6-003.9

REHABILITATION OF ONCOLOGICAL PATIENTS: THE COMPLEXITY OF THE PROBLEM

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Abstract

This scientific and analytical publication describes modern directions of rehabilitation of cancer patients with various localization of the tumor process. The currently available methods of rehabilitation treatment and scientific directions that require further research to improve the quality of life of this contingent of patients are described. The use of a comprehensive program of medical rehabilitation in cancer patients will restore their vital conditions as much as possible and will optimize the processes of physical, psychological and social adaptation of these patients, which is the main task of oncology and rehabilitation today.

Keywords: oncology, rehabilitation, quality of life.

Today, high rates of incidence of malignant tumors and a priori aggressive treatment methods and, often, the prevalence of the oncological process itself lead to disability, requiring rehabilitation measures. In this regard, such a section of clinical oncology as the rehabilitation of cancer patients must be on the same level with modern treatment, diagnosis and prevention of cancer [1,2].

It is important to especially emphasize that rehabilitation measures begin not after the patient develops various kinds of physical and psycho-emotional dysfunctions as a result of specialized treatment and (or) complications of the tumor process, but already from the moment the diagnosis of a malignant neoplasm is made. At the same time, patients registered with an oncologist often experience various kinds of functional disorders that affect their quality of life and ability to work. For example, physical disorders may include fatigue, decreased muscle strength, cognitive dysfunction, paraesthesia, or eating problems, while mental symptoms may include anxiety, depression, fear of relapse, or insomnia. In this regard, the role of rehabilitation doctors and the importance of specialists with the skills of professional assessment and therapy in oncology services in this situation can hardly be overestimated [3].

One of the important aspects of complex rehabilitation of cancer patients is the use of drug correction of the psycho-emotional state of cancer patients, which previously received little attention. It is clear that oncologists and rehabilitation specialists take on this difficult role, but in some, quite common cases, additional drug support for the patient's psyche is required [4,5].

Thus, Taiwanese researchers Cheng-Hsu Wang et al. [6] not only analyzed, but also proved that the need

for psychotropic drugs depends on the nosological form of the tumor. They analyzed data from 35,137 cancer patients from Taiwan's National Health Insurance database over 2.5 years. Among those patients who survived for at least 6 months, every fifth (20.9%) used psychotropic drugs: patients were most often prescribed sedatives (14.3%), then antidepressants (5.5%), anxiolytics (3.6%) and antipsychotics (2.7%). Lung cancer, prostate cancer and oral cancer showed a statistically significant association with regular drug use during the first six months after diagnosis. And among patients who survived for at least 2.5 years, 4.8% still use psychotropic medications on a regular basis.

Catherine L. Granger et al. [7] found through a systematic review of articles using the electronic databases Medline, Cinahl, Embase, Scopus and Cochrane that despite evidence and existing guidelines for physical activity in patients with lung cancer, it is hardly implemented in clinical practice. This systematic review of the literature showed that the challenges of adequate physical rehabilitation of patients with lung cancer are multifaceted and involve various factors. These include patient-level factors such as symptoms, comorbidities, sedentary lifestyle, mood and fear, and environmental factors. These factors should be taken into account to determine and develop a treatment and rehabilitation program for these patients.

In addition, very little attention is often paid to the fact that the main moral burden when caring for cancer patients falls, of course, on their loved ones. And, unfortunately, according to Swedish researchers Ji J. et al. [8] spouses of cancer patients who provide care are at increased risk of coronary heart disease and stroke. This is necessary to know for the correct approach to correcting the psychological state of not only the patient himself, but also their relatives (family rehabilitation).

At the same time, Badr H. et al. [9] found a low level of self-efficacy and a high level of distress when independently caring for patients with advanced lung cancer. The authors, based on experimental studies in which 39 patients took part, developed a program to coordinate care and train care skills for such patients. The program was based on self-determination theory. Participants reported significant reductions ($p<0.0001$) in depression, anxiety, and caregiving burden, increased caregiver competence, and caregiver autonomy to provide care compared to usual care.

Similar results were obtained in their study by Kim Y. et al. [10]. The authors note that the difficulty of psychological adaptation of relatives in families in which there is a cancer patient and the lack of social support are the main predictors of the development of major depressive disorders, even 3 years after diagnosis. At the same time, programs for adaptation to long-term care are crucial for the possibility of long-term (5-year results were taken into account) active care for the patient.

In addition, El-Jawahri A. et al. [11] found that patients' inadequate perception of their prognosis regarding cancer affects many of their decisions about medical care. However, the relationships between prognostic perception, quality of life, and patient mood itself are not yet fully understood. They stated the fact that, although patients wanted to know detailed information about their illness, half incorrectly perceived the fact that the prognosis in their situation was favorable. Of the 50 patients included in the study, 38 (76%) wanted to know as many details as possible about their diagnostic procedures and treatments. However, 25 of 50 patients (50%) stated that their goal was to "cure cancer," and only 10 of 49 patients (20%) reported that they had completely "put their fate in the hands of their oncologist." Patients who accepted their illness as a death sentence reported lower quality of life ($p=0.005$) and higher levels of anxiety ($p=0.003$) compared to those who did not perceive themselves as terminally ill. The authors established a direct connection between accurate prognostic perception and the quality of life of patients. Therefore, interventions aimed at improving understanding of disease prognosis provide adequate psychosocial support for these people.

Any methods, as we all understand perfectly well, should be used to alleviate the condition of cancer patients and restore their well-being. Such methods include art therapy, which, of course, belongs to non-traditional methods of influence, but with a comprehensive program of restorative treatment it shows its effectiveness.

Lee J. et al. [12] decided to evaluate the effect of art therapy using paintings by famous artists on the manifestation of long-term chronic stress (distress) in cancer patients receiving radiation therapy. The level of anxiety, depression and symptoms associated with the manifestation of the cancer itself were assessed. The authors conducted a prospective study that included 24 cancer patients with various forms of malignant neoplasms who received radiation therapy. Art therapy took place in two parts, including 4 sessions of a famous painting course and 4 sessions of works of art of the creative generation; these sessions were held twice a week for four weeks. Distress was assessed using the Hospital Anxiety and Depression Scale (HADS), the Hamilton Depression Rating Scale (HDRS), and the Edmonton Symptom Assessment Scale (ESAS) at three assessment points: before the start of art therapy, after the fourth session, and then after the eighth session. art therapy. It was found that of the 24 patients included in the study, 20 patients (83%) completed all eight sessions. At the same time, the authors note a significant and even significantly significant decrease in indicators of depression

and anxiety on all scales used in the study.

It should be noted that a number of nosological forms of malignant tumors and crippling surgical interventions used in these diseases, such as enucleation of the eye, removal of the obturator apparatus of the rectum, breast extirpation lead to the deepest physical, psychological and social disability of patients. Laryngeal cancer is one of these localizations of the oncological process.

A very interesting and important study on this subject was carried out by Millgård M., Tuomi L. [13]. The study aimed to investigate the short-term and long-term effects of voice rehabilitation in patients treated with radiotherapy for laryngeal cancer as measured by both the acoustic measure smoothed cepstral peak prominence (CPPS) and perceptual measures. A secondary aim was to investigate the relationship between acoustic and perceptual measures. In total, 37 patients received voice rehabilitation post-radiotherapy and 37 patients constituted the irradiated control group. Outcome measures were mean CPPS for connected speech and ratings with the auditory-perceptual Grade, Roughness, Breathiness, Asthenia and Strain (GRBAS) scale. Outcome measures were analyzed 1 (baseline), 6, 12, and 24 months post-radiotherapy, where voice rehabilitation was conducted between the first two time-points. Additional recordings were acquired from vocally healthy participants for comparison. As a result, CPPS values of the voice rehabilitation group and vocally healthy group were not significantly different at 24 months post-radiotherapy. Ten out of 19 patients who received voice rehabilitation yielded a CPPS value above the threshold for normal voice 24 months post-radiotherapy, compared to 11 out of 26 in the irradiated control group. No statistically significant correlations were found between CPPS and perceptual parameters of GRBAS. Based on the results obtained, the authors conclude that voice rehabilitation for irradiated laryngeal cancer patients may have positive effects on voice quality up to 24 months post-radiotherapy. The relationship between CPPS and GRBAS as well as the applicability of CPPS for evaluation over several points of measurement needs to be studied further.

In their paper, Zhu X. et al. [14] emphasize that dysphagia is a common complication in patients with laryngeal cancer after surgery and radiotherapy. The aim of the study was to study the impact of swallowing training administered in combination with nutritional intervention on the nutritional status and quality of life of laryngeal cancer patients with dysphagia after surgery and radiotherapy. Sixty-six patients with laryngeal cancer who developed dysphagia were randomly divided into control group and intervention group (n = 33 in each group). Patients in both groups received total laryngectomy and prophylactic radiotherapy and were provided routine health counseling and swallowing training. Patients in the intervention group were additionally provided with nutritional intervention. All patients were evaluated using video fluoroscopic swallowing examination (VFSE), Patient-Generated Subjective Global Assessment on nutritional status (PG-SGA) score, and Quality of Life Questionnaire-core 30 (QLQ-c30) score immediately after radiotherapy and 3 months later. The results were as follows: prior to swallowing training, there was no significant between-group difference with respect to VFSE evaluation, PG-SGA score, or QLQ-c30 score. Both groups showed improvement in these measures at 3 months after radiotherapy; however, the improvement in the intervention group was significantly better than that in the control group. The researchers conclude that swallowing training combined with nutritional intervention can improve swallowing function, nutritional status and the quality of life of laryngeal cancer patients with dysphagia after operation and radiotherapy.

As noted by Salerno G. et al. [15], total laryngectomy represents the surgical procedure necessary for the treatment of some advanced neoplasms of the hypopharyngeal-laryngeal district and involves strong functional, physical and emotional repercussions. In their study, our colleagues examined how rehabilitation techniques used to improve the communication needs of patients who have undergone laryngectomy affect their perception of quality of life. The questionnaires "V-RQoL" and "SECEL" were administered to 45 patients divided into four groups on the basis of the type of vicarious voice: group TE (27 patients), group E (7 patients), group EL (2 patients), group NV (9 patients). Patients using electrical or tracheo-esophageal prostheses reported a better quality of life than patients with an erythromophonic voice. Regarding postoperative satisfaction, the group with esophageal voice was the most satisfied. The authors emphasize the importance of preoperative counseling to make the patient as aware as possible of his future condition.

Retinoblastoma is an intraocular cancer of infancy and childhood, which has been treated with radiation therapy and chemotherapy. Radiation on growing patients can cause deterioration in maxillofacial growth and development that leads to severe skeletal discrepancies between the maxilla and mandible, and dental problems such as crossbite, openbite, and hypodontia. Kim S.H. et al. [16] presented a case of a 19-year-old Korean man with chewing disability and dentofacial deformities. He had undergone enucleation of the right eye and radiation therapy of the left eye due to retinoblastoma 100 days after birth. Subsequently, he received cancer therapy for the secondary nasopharyngeal cancer at the age of 11 years. He was diagnosed with severe skeletal deformity including sagittal, transverse, and vertical growth deficiency of the maxilla and midface, and with class III malocclusion, severe anterior and posterior crossbite, posterior openbite, multiple missing upper incisors,

right premolars, and second molars, and impaction of the lower right second molars. To restore impaired functions and esthetics of the jaw and dentition, the orthodontic treatment combined with two jaw surgery was performed. At the end of surgical orthodontics, dental implants were placed for prosthetic treatment of missing teeth. Additional plastic surgery for zygoma elevation was done with calvarial bone graft followed by fat graft. Facial esthetics and occlusal functions of patient were favorably enhanced with the improvement of skeletal discrepancy and the rehabilitation of maxillary dentition by prosthetic work. At the 2-year follow-up, the skeletal and dental relationships and implant prosthetics were well maintained. The authors conclude as follows: in an adult patient with dentofacial deformities caused by early cancer therapy in the head and neck area, interdisciplinary interventions including additional plastic surgery of zygoma depression and prosthetic work of missing teeth as well as surgical-orthodontic treatment could establish favorable facial esthetics and oral rehabilitation.

The case of eyeball prosthetics was presented in their study by Goiato M.C. et al. [17]. Male patient, 60 years old, sought care at the Oral Oncology Center of the São Paulo State University "Júlio de Mesquita Filho", for the rehabilitation of the orbital cavity with an acrylic eye prosthesis. This prosthesis was made with thermopolymerizable acrylic resin and hand painted iris with oil paint on cardboard. The prosthesis was installed after finishing and polishing and the hygiene and general care instructions were explained. Colleagues focus on the fact that the lack of an eye has an immediate and long-term impact on a patient's life. In the present case, the patient was satisfied with the aesthetics and comfort of the prosthesis, which demonstrates the success of the treatment.

As Rokohl A.C. et al. [18] show, a smooth supply with a visually appealing prosthetic eye after enucleation is not just a cosmetic solution, it is also a key factor in successful social and psychological rehabilitation. The authors submitted an overview of the current state of medical and ocular care regarding prosthetic eyes in Germany. It focuses mainly on the newest clinical results, daily care, complications, and psychological aspects of wearing prosthetic eyes. As a result of the latest clinical data and a current review of the PubMed literature, it was found that in Germany, enucleated patients normally get a double-walled, hollow prosthetic eye made of cryolite glass, and patients with a microphthalmic or phthisic eye receive a thin single-walled prosthesis. Anophthalmic patients wearing cryolite glass prosthetic eyes seem to be more satisfied with their appearance and the look of their prostheses than polymethylmethacrylate (PMMA) prosthetic eye wearers. Cryolite glass prosthetic eyes must be renewed at least each year, while PMMA prostheses need to be polished once a year and renewed after five years of wearing. Among children, the fit of the prosthetic eye must be checked, based on growth, semi-annually. A slightly higher risk of breakage of cryolite glass prostheses is, for most patients, not a great disadvantage in everyday life. Ocularists and ophthalmologists should determine an individual cleaning regime, together with the patient, that is dependent on the material of the ocular prosthesis and other external factors. Complications, such as allergic, giant papillary, viral and bacterial conjunctivitis and blepharoconjunctivitis sicca must be treated at an early stage to allow for a prosthetic eye. In the case of inflammation-caused socket shrinkage or post-enucleation socket syndrome, surgical interventions are needed to reenable the use of a prosthetic eye. Since the health of the remaining eye is the major psychological burden of prosthetic eye wearers, good ophthalmological care and medical screenings are essential elements. In conclusion, the researchers conclude that a smooth supply with a prosthetic eye, adequate and early treatment of possible complications and attention to psychological aspects is essential for successful long-term rehabilitation of enucleated patients.

As well as patients with previous localizations of the oncological process, patients with colorectal cancer with colostomies need mandatory rehabilitation measures.

Thus, Yang P. et al. [19] set themselves the goal of to systematically evaluate the effect of collaborative nursing on self-care ability of postcolostomy patients with colorectal cancer (CRC). PubMed, Web of Science, Embase, China National Knowledge Infrastructure, and Wanfang databases were searched to collect relevant literatures on randomized controlled trials of postcolostomy patients with CRC. The search period was started from 2010 to 2021. Statistical analysis was performed on the data extracted from the comprehensive meta-analysis with STATA 16.0 analysis software. As a result, it was found that the incidence of adverse reactions in the control group was higher than that in the treatment group. Seven studies included the preintervention self-care concept and preintervention self-care skills. Six studies included preintervention self-care responsibility and preintervention exercise of self-care agency (ESCA) scale. In the comparison among the concept of self-care after intervention, self-care skills, self-care responsibility, and ESCA scale, all of them had higher scores in the treatment group than in the control group ($p<0.05$). It fully explains that collaborative nursing can significantly improve the evaluation indicators of patients' self-care ability and reduce patient complications. In summary, the authors conclude that the application of collaborative nursing in the nursing work of patients with CRC after colostomy can significantly reduce the incidence of adverse nursing reactions.

The aim of the work is Yu S., Tang Y. [20] to explore the impacts of comprehensive care on psychological emotion, postoperative rehabilitation and complications of colorectal cancer patients after colostomy. From August 2018 to February 2020, a total of sixty colorectal cancer patients undergoing colostomy in our hospital were collected and randomly assigned to a control group to receive conventional care and a research group to receive comprehensive care, with 30 patients in each group. The two groups of patients were compared for postoperative recovery, complications, adverse psychological emotions, self-care ability, quality of life, and nursing satisfaction. The first time of exhaust, food intake and the recovery of bowel sound in the research group were markedly earlier than those in the control group. Besides, the research group had notably lower incidence of postoperative complications, lower self-anxiety scale (SAS) and self-depression scale (SDS) scores at discharge, and higher average self-care ability than the control group, as well as higher quality of life score and nursing satisfaction. At the end of the work, it was concluded that comprehensive care intervention can promote postoperative recovery of colorectal cancer patients after colostomy, relieve their negative emotions, reduce postoperative complications, improve quality of life and nursing satisfaction, which are all important and make this type of care worthy of promotion in clinical practice.

A study by Wang S.Y. et al. [21] examined the effects of a multimedia patient education intervention on improving self-care knowledge and skills in patients with colorectal cancer who underwent colostomy surgery. A quasi-experimental design was adopted to measure the self-care knowledge and skills of patients with colorectal cancer before and after surgery. The experimental group (n = 33) received a multimedia patient education intervention, whereas the control group (n = 30) was provided conventional instructions. Results were evaluated using analysis of covariance. On the day prior to discharge from hospital, the experimental group exhibited significantly greater improvement in self-care knowledge than did the control group. The experimental group also exhibited significantly greater improvement in self-care skills than did the control group on the day of gas passage, the day prior to discharge from hospital, and during the first clinic visit after discharge from the hospital. In other words, multimedia patient education intervention yielded greater improvement in self-care knowledge and skills than did conventional instruction. The authors state that multimedia patient education is an adequate educational tool for patients with colorectal cancer who have undergone colostomy.

Now, regarding the rehabilitation of patients with breast cancer.

The leading method of treating malignant neoplasms, including breast cancer, is surgical. As Chan K.S. points out. et al. [22], functional results are increasingly important in breast cancer, as survival and prognosis for this pathology improve over the years. Since more than half of diagnosed breast cancer cases occur in middle-aged women between 45 and 64 years of age, it is appropriate to ensure preservation of upper extremity function as this group of patients may be the primary caregivers for their families, lead active lifestyles, and are at the peak of their careers. Additionally, most previous studies have shown that Asians may have higher body fat percentages, lower bone mass, and lower levels of physical activity than Western populations. These factors may influence functional outcomes in patients with breast cancer. The authors conducted a single-center prospective cohort study with a follow-up period of 6 weeks after surgery. The main inclusion criteria were patients over 21 years of age who underwent 44 radical surgical interventions - wide sectoral resection - 16 (36.4%) and mastectomy - 28 (63.6%). The main exclusion criteria were patients with pre-existing neurological or rheumatological comorbidities affecting upper limb function, or previous trauma that resulted in upper limb deformity. Patients who had undergone mastectomy with reconstruction were also excluded. The patients underwent early rehabilitation from the 1st day after surgery, including a standardized set of exercises for the shoulders and upper extremities. Active shoulder flexion and abduction range of motion and disability scores were assessed 1 week before surgery and then at weeks 2 and 6 postoperatively. This pilot study in an Asian cohort showed that patients were able to regain active range of motion of shoulder flexion and abduction at 6 weeks postoperatively, but had a worse disability score, especially in the axillary lymph node dissection subgroup after sentinel lymph node examination. Recommendations include the use of active early rehabilitation methods for breast cancer patients, however, as the authors note, longer follow-up is required to assess long-term functional results.

The modern direction in medical rehabilitation of patients with breast cancer, as well as in their treatment today, is the individualization of the treatment and rehabilitation program. As Olsson Möller U. et al. note in their publication [23], it is well known that women suffer from the negative consequences of breast cancer treatment and that their very important needs during rehabilitation interventions are often not met. At the same time, up to 43% of these women are at risk of developing chronic distress, requiring comprehensive treatment. However, it is unknown how to identify and meet the needs of these women early, leaving them with a low chance of optimal rehabilitation. The authors plan to conduct a three-arm randomized controlled trial and aim

to develop a model and evaluate the effect of individualized screening-based rehabilitation after primary treatment for breast cancer. The rehabilitation program will be based on self-reported data, focusing on physical and psychological outcomes, as well as treatment satisfaction at baseline at 2 weeks, 3, 6, 9 and 12 months. The assessment will also include economic aspects of health, based on register data and information from patients and their relatives during the rehabilitation process. In addition, optimal threshold levels of negative behaviors will be explored as an indicator of the need for extended rehabilitation. It is planned to identify potential new problems and rehabilitation needs of patients during the 1-year follow-up period. The researchers note that this study will provide important knowledge regarding the effectiveness of screening to identify needs for individualized, standardized, evidence-based rehabilitation after primary breast cancer treatment.

Much work regarding the development of a rehabilitation program for patients with breast cancer has been carried out by Spanish scientists and clinicians Barnadas A. et al. [24]. As the researchers emphasize, the gradual increase in incidence associated with the aging population and the implementation of screening programs, together with lower mortality rates from breast cancer, has led to an increase in the number of surviving patients with this pathology. The treatment used leaves physical, psychological and psychosocial consequences that can manifest and persist even years after completion of treatment and can interfere with the well-being of breast cancer patients and their reintegration into normal social and professional activities. Complications of the underlying disease and concomitant pathology require joint monitoring by specialized medical institutions and primary health care services. The authors have compiled guidelines aimed at ensuring joint and coordinated monitoring of these patients by these medical services. The guideline addresses health problems arising from treatment, with recommendations for a therapeutic approach that individualizes treatment, as well as suggestions for coordinated joint monitoring by primary and secondary care. In addition to organizational issues, the guide provides general recommendations for breast cancer patients: 1) avoid excess weight, 2) healthy diet and exercise, 3) quit smoking, 4) moderate alcohol consumption, 5) possible use of additional treatment methods, for example, such as acupuncture, 6) awareness of symptoms indicating a possible relapse or recurrent tumor, 7) adherence to prescribed anti-estrogenic hormone therapy for a long period (5-10 years), 8) return to work.

In addition, one of the modern methods of restorative treatment of cancer patients includes a method such as neuromuscular electrical stimulation (NMES) [25]. It may be a pragmatic short-term alternative to voluntary exercise in patients who are currently undergoing or have recently completed treatment for cancer. In this study, the authors assessed the impact of a personalized and progressive NMES exercise intervention, designed with the early rehabilitation period in mind, on patients' physical performance and quality of life. This manipulation was found to improve performance on the 30-second sitting test (STS), the 6-minute walking test (6 MW), and global quality of life using the EORTC QLQ C-30 questionnaire. Benefits gained included improved muscle strength and greater confidence when walking. The authors recommend further evaluation of this technique in a further controlled prospective study.

Wang Y. et al. [26] indicate that epidemiological studies consistently demonstrate an inverse association between physical activity levels and the risk of developing gynecological cancers, as well as improved survival outcomes among cancer survivors engaging in regular exercise. Mechanistic insights suggest that physical activity and exercise may modulate key pathways involved in carcinogenesis, tumor progression, and treatment response, offering promising avenues for preventive and adjunctive therapeutic interventions. However, despite a growing body of research in exercise oncology, there is a lack of disease-specific synthesis addressing how exercise can be tailored to the distinct pathophysiological, treatment-related, and psychosocial challenges of gynecological cancers. Current guidelines often generalize exercise recommendations across all cancer types, overlooking the unique symptom burdens, such as pelvic floor dysfunction, sarcopenia, and menopausal symptoms, specific to gynecologic malignancies. Beyond cancer-type-specific exercise programs, a significant aspect of survivorship care for gynecological cancer patients involves addressing psychosocial and functional needs that affect both physical and emotional well-being. Several interventions have sought to integrate exercise and rehabilitation programs with psychosocial support to help gynecologic cancer survivors better cope with treatment-related challenges and improve their overall quality of life. These programs aim not only to enhance physical fitness but also to address the emotional and psychological distress that often accompanies cancer treatment and recovery. These studies collectively emphasize that exercise interventions, when combined with psychosocial support, are crucial for improving physical health while also addressing the psychological and emotional burdens faced by gynecologic cancer survivors. Therefore, integrating flexible, behaviorally supported, and symptom-specific rehabilitation strategies into routine oncology care is essential to optimize both physical and mental health outcomes in these patients. By adopting a multidimensional research framework and addressing these gaps, the full therapeutic potential of lifestyle interventions may be realized to improve clinical outcomes and survivorship. Emphasis should also be placed on advancing molecular and

translational research to bridge mechanistic understanding with clinical application, thereby informing more precise and biologically grounded exercise prescriptions in gynecologic oncology.

In recent years, the term "multimodal" has been increasingly used in clinical research, which means, according to Wiktionary, involving or using several methods or modes of implementation. When analyzing a review of the literature related to multimodal rehabilitation of cancer patients, it should be noted that the overwhelming number of scientific works are devoted to the use of rehabilitation measures at the stage of preparing patients for specialized treatment, be it surgery or courses of drug or radiation therapy.

Guinan E.M. et al. [27] note in their work that the inflammatory changes themselves and the disruption of redox processes after radical surgery for esophageal cancer significantly affect both the quality of life and the survival of patients. In this regard, an integrated approach to the rehabilitation of these patients, including special exercises and a certain diet, can reduce the negative manifestations of the treatment. However, the authors note that the results will be further examined in a larger randomized controlled trial. In addition to the impact of these manifestations on the survival of patients, the economic side of the full rehabilitation of these patients will also be studied.

Bolshinsky V. et al. [28], based on an analysis of studies on multimodal rehabilitation programs before surgery for gastrointestinal tumors, conducted a systematic literature search using Medline, PubMed, Embase, Cinahl, Cochrane and Google Scholar databases. Study quality was assessed using the Cochrane Risk of Bias Tool (randomized trials) and the Newcastle-Ottawa Quality Assessment Scale (cohort studies). Of the 544 studies identified, 20 were included in the qualitative analysis. The authors found that although small studies have found encouraging results, larger prospective studies using uniform objective risk stratification and structured interventions with prespecified clinical and economic endpoints are needed to determine the definitive value of prehabilitation programs.

Summing up the analyzed works on rehabilitation measures in cancer patients with various nosological forms of malignant neoplasms, we can draw a definite conclusion that a multifaceted approach is required when conducting rehabilitation treatment in these patients, aimed at compensating for impaired body functions, improving the quality of life, reducing the severity of disability and prolonging active life. The process of recreating the vital status of patients is multidimensional and requires an integrated approach to restore the physical, psycho-emotional and social conditions of patients. At the same time, almost all authors agree on one thing: further multicenter randomized studies are needed to develop standardized approaches to conducting rehabilitation measures in cancer patients.

References

1 Kaidarova D.R., Shatkovskaya O.V., Ongarbayev B.T., Seisenbayeva G.T., Azhmagambetova A.E., Zhylkaidarova A.Zh., Lavrentieva I.K., Sagi M.S. Indicators of the oncology service of the Republic of Kazakhstan, 2022: statistical and analytical materials. – Almaty, 2023. – 430 p.

2 Global Burden of Disease Cancer Collaboration. Global, Regional, and National Cancer Incidence, Mortality, Years of Life Lost, Years Lived With Disability, and Disability-Adjusted Life-Years for 29 Cancer Groups, 1990 to 2017: A Systematic Analysis for the Global Burden of Disease Study. JAMA Oncol. 2019 Dec 1;5(12):1749-1768. doi: 10.1001/jamaoncol.2019.2996.

3 Neo J., Fettes L., Gao W., Higginson I.J., Maddocks M. Disability in activities of daily living among adults with cancer: A systematic review and meta-analysis. Cancer Treat Rev. 2017 Dec;61:94-106. doi: 10.1016/j.ctrv.2017.10.006.

4 Heß V., Meng K., Schulte T., Neuderth S., Bengel J., Jentschke E., Zoll M., Faller H., Schuler M. Unexpressed psychosocial needs in cancer patients at the beginning of inpatient rehabilitation: a qualitative analysis. J Psychosoc Oncol. 2021;39(2):173-188. doi: 10.1080/07347332.2020.1819931.

5 Hass H.G., Seywald M., Wöckel A., Muco B., Tanriverdi M., Stepien J. Psychological distress in breast cancer patients during oncological inpatient rehabilitation: incidence, triggering factors and correlation with treatment-induced side effects. Arch Gynecol Obstet. 2023 Mar;307(3):919-925. doi: 10.1007/s00404-022-06657-3.

6 Cheng-Hsu Wang, Lynn Chu Huang, Chen-Chang Yang, Chi-Liang Chen, Yiing-Jenq Chou, Yen-Yuan Chen, Wei-Chih Yang, Likwang Chen. Short- and long-term use of medication for psychological distress after the diagnosis of cancer. Support Care Cancer. 2017 Mar;25(3):757-768. doi: 10.1007/s00520-016-3456-z.

7 Granger C.L., Connolly B., Denehy L., Hart N., Antippa P., Lin K.Y., Parry S.M. Understanding factors influencing physical activity and exercise in lung cancer: a systematic review. Support Care Cancer. 2017 Mar;25(3):983-999. doi: 10.1007/s00520-016-3484-8.

8 Ji J., Zöller B., Sundquist K., Sundquist J. Increased risks of coronary heart disease and stroke among

spousal caregivers of cancer patients. Circulation. 2012 Apr 10;125(14):1742-7. doi: 10.1161/CIRCULATIONAHA.111.057018.

9 Badr H., Smith C.B., Goldstein N.E., Gomez J.E., Redd W.H. Dyadic psychosocial intervention for advanced lung cancer patients and their family caregivers: results of a randomized pilot trial. Cancer. 2015 Jan 1;121(1):150-8. doi: 10.1002/cncr.29009.

10 Kim Y., Shaffer K.M., Carver C.S., Cannady R.S. Prevalence and predictors of depressive symptoms among cancer caregivers 5 years after the relative's cancer diagnosis. J Consult Clin Psychol. 2014 Feb;82(1):1-8. doi: 10.1037/a0035116.

11 El-Jawahri A., Traeger L., Park E.R., Greer J.A., Pirl W.F., Lennes I.T., Jackson V.A., Gallagher E.R., Temel J.S. Associations among prognostic understanding, quality of life, and mood in patients with advanced cancer. Cancer. 2014 Jan 15;120(2):278-85. doi: 10.1002/cncr.28369.

12 Lee J., Choi MY, Kim YB, Sun J, Park EJ, Kim JH, Kang M, Koom WS. Art therapy based on appreciation of famous paintings and its effect on distress among cancer patients. Qual Life Res. 2017 Mar;26(3):707-715. doi: 10.1007/s11136-016-1473-5. Epub 2016 Dec 7. PMID: 27928697.

13 Millgård M., Tuomi L. Voice Quality in Laryngeal Cancer Patients: A Randomized Controlled Study of the Effect of Voice Rehabilitation. J Voice. 2020 May;34(3):486.e13-486.e22. doi: 10.1016/j.jvoice.2018.09.011.

14 Zhu X., Liu D., Zong M., Wang J. Effect of swallowing training combined with nutritional intervention on the nutritional status and quality of life of laryngeal cancer patients with dysphagia after operation and radiotherapy. J Oral Rehabil. 2022 Jul;49(7):729-733. doi: 10.1111/joor.13328.

15 Salerno G., Villari P., Catalano V., Sivero L., Maldonato M.N., Bottone M., Sivero S. Voice rehabilitation and quality of life in laryngectomized patients. Ann Ital Chir. 2023;94:7-10.

16 Kim S.H., Choi T.H., Lee Y.S., Kim Y.K., Jo D.W., Kim B.K., Choi H.L., Lee N.K. Rehabilitation of severe dentofacial deformity after early radiotherapy of retinoblastoma: a case report. J Med Case Rep. 2023 Mar 9;17(1):103. doi: 10.1186/s13256-023-03761-z.

17 Goiato M.C., Dos Santos D.M., de Sousa Ervolino I.C., Brunetto .JL., de Magalhaes Bertoz A..P, de Moraes Melo Neto C.L. Prostetic Rehabilitation of an Eye Globe: Case Report. Med Arch. 2019 Dec;73(6):433-435. doi: 10.5455/medarh.2019.73.433-435.

18 Rokohl A.C., Mor J.M., Trester M., Koch K.R., Heindl L.M. Rehabilitation of Anophthalmic Patients with Prosthetic Eyes in Germany Today - Supply Possibilities, Daily Use, Complications and Psychological Aspects]. Klin Monbl Augenheilkd. 2019 Jan;236(1):54-62. doi: 10.1055/a-0764-4974.

19 Yang P., Shan R., Wei Y., Ni J., Chen H., Yang C., Yan H., Shen B. Meta-Analysis on the Application Value of Collaborative Nursing in Postcolostomy Nursing of Patients with Colorectal Cancer. Comput Math Methods Med. 2022 Jan 30;2022:6940715. doi: 10.1155/2022/6940715. eCollection 2022.

20 Yu S., Tang Y. Effects of comprehensive care on psychological emotions, postoperative rehabilitation and complications of colorectal cancer patients after colostomy. Am J Transl Res. 2021 Jun 15;13(6):6889-6896. eCollection 2021.

21 Wang S.Y., Chang T.H., Han C.Y. Effectiveness of a Multimedia Patient Education Intervention on Improving Self-care Knowledge and Skills in Patients with Colorectal Cancer after Enterostomy Surgery: A Pilot Study. Adv Skin Wound Care. 2021 Feb 1;34(2):1-6. doi: 10.1097/01.ASW.0000725192.98920.c4.

22 Chan K.S., Zeng D., Leung J.H.T., Ooi B.S.Y., Kong K.T., Yeo Y.H., Goo J.T.T., Chia C.L.K. Measuring upper limb function and patient reported outcomes after major breast cancer surgery: a pilot study in an Asian cohort. BMC Surg. 2020 May 19;20(1):108. doi: 10.1186/s12893-020-00773-0.

23 Olsson Möller U., Rydén L., Malmström M. Systematic screening as a tool for individualized rehabilitation following primary breast cancer treatment: study protocol for the ReScreen randomized controlled trial. BMC Cancer. 2020 May 29;20(1):484. doi: 10.1186/s12885-020-06815-3.

24 Barnadas A., Algara M., Cordoba O., Casas A., Gonzalez M., Marzo M., Montero A., Muñoz M., Ruiz A., Santolaya F., Fernandez T. Recommendations for the follow-up care of female breast cancer survivors: a guideline of the Spanish Society of Medical Oncology (SEOM), Spanish Society of General Medicine (SEMERGEN), Spanish Society for Family and Community Medicine (SEMFYC), Spanish Society for General and Family Physicians (SEMG), Spanish Society of Obstetrics and Gynecology (SEGO), Spanish Society of Radiation Oncology (SEOR), Spanish Society of Senology and Breast Pathology (SESPM), and Spanish Society of Cardiology (SEC). Clin Transl Oncol. 2018 Jun;20(6):687-694. doi: 10.1007/s12094-017-1801-4.

25 O'Connor D., Fernandez M.M., Signorelli G., Valero P., Caulfield B. Personalised and progressive neuromuscular electrical stimulation (NMES) in patients with cancer-a clinical case series. Support Care Cancer. 2019 Oct;27(10):3823-3831. doi: 10.1007/s00520-019-04679-3.

26 Wang Y, Malek M. Molecular, cellular, biochemical, and rehabilitative insights into exercise interventions for gynecological cancer prevention and survivorship: a narrative review. J Ovarian Res. 2025 Jul 5;18(1):147. doi: 10.1186/s13048-025-01725-z. PMID: 40618154; PMCID: PMC12228313.

27 Guinan E.M., Doyle S.L., O'Neill L., Dunne M.R., Foley E.K., O'Sullivan J., Reynolds J.V., Hussey J. Effects of a multimodal rehabilitation programme on inflammation and oxidative stress in oesophageal cancer survivors: the ReStOre feasibility study. Support Care Cancer. 2017 Mar;25(3):749-756. doi: 10.1007/s00520-016-3455-0.

28 Bolshinsky V., Li M.H., Ismail H., Burbury K., Riedel B., Heriot A. Multimodal Prehabilitation Programs as a Bundle of Care in Gastrointestinal Cancer Surgery: A Systematic Review. Dis Colon Rectum. 2018 Jan;61(1):124-138. doi: 10.1097/DCR.0000000000000987.

Pedagogical sciences

INCLUSIVE EDUCATION IN CHINA AND KAZAKHSTAN: A COMPARATIVE ANALYSIS

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Introduction

In the context of globalization and the transition to the principles of development and social justice, inclusive education is becoming one of the main directions of public education policy in many countries. It aims to ensure equal access to quality education for all students, including children with special educational needs.

China and Kazakhstan, despite their differences in socio-economic development and educational traditions, have been actively reforming their education systems towards inclusivity in recent years[1]. Currently, there are common trends in both countries, but there are also differences in implementation mechanisms, institutional features, and the level of practical support for educational organizations.. In this regard, it seems relevant to conduct a comparative analysis of the experience of China and Kazakhstan in the field of inclusive education. This will make it possible to determine the effectiveness of this model, identify possible problems and outline development prospects, taking into account the ongoing educational policy.

The purpose of the study is to conduct a comparative analysis of inclusive education systems in China and Kazakhstan, to identify common features, peculiarities and factors contributing to successful practice.

To achieve this goal, it is necessary to solve the following tasks:

1. To consider the regulatory framework and conceptual approaches to the development of inclusive education in China and Kazakhstan.

2. To study the specifics of the practical implementation of inclusive education, including organizational mechanisms, teacher training and forms of student support, taking into account educational requirements.

The research raised scientific and research questions: What are the key similarities and differences in the models of inclusive education in China and Kazakhstan? What elements of the Chinese and Kazakh experience can be adapted to improve the effectiveness of national educational systems?

The scientific novelty of the research lies in a comprehensive comparative analysis of inclusive education in two countries with different socio-cultural and institutional conditions of development. This allows not only to generalize existing approaches, but also to identify new complementary elements of inclusion models.

Unlike studies focused on the analysis of a single national system, this work focuses on cross-country comparison and allows for the transfer of educational practices.

The theoretical significance of the research is aimed at expanding scientific understanding of inclusive education as a socio-pedagogical phenomenon, as well as clarifying conceptual approaches to the comparative analysis of education systems in conditions of multiple inclusion.

The practical significance of the research lies in the possibility of using the findings and recommendations in the activities of educational authorities, educational organizations and in the training of teaching staff. The research results can be applied in the development of programs for the development of inclusive education, methodological recommendations and strategies in Kazakhstan and other countries based on international experience.

Literature review

Within the framework of this scientific field, inclusive education is a key aspect of the reform of the education system. However, along with this, there are specific features and problems.

Wu Jiezhen's article presents a sociological analysis of inclusive education in modern Chinese society[2]. The author comes to the conclusion that the development of this educational policy is determined by a number of factors, such as government policy, social attitudes, cultural characteristics and conditions.

It is noted that the current models of inclusive education in China do not yet fully comply with international standards, classifications of forms of disability and requirements for infrastructure that ensures

accessibility and quality of education for children, taking into account all educational needs. The author suggests improving the qualifications of teaching staff and increasing investments in the inclusive education system as a way to overcome existing problems.

In a more comprehensive analysis, Wangqian Fu's book “Inclusive Education in China: Ideas, Practice, and Challenges” examines the historical formation and contemporary practice of inclusive education in China[3]. The author analyzes the phenomenon of regular classroom (LRC) education, which has historically been a key form of inclusion in Chinese schools, where children with special needs are integrated into regular classes, but in this direction there are concerns about the future transformation of the education process for these students.

The author emphasizes the philosophical, political, and cultural aspects that impact the implementation of inclusion. They draw attention to the lack of significant progress in educational programs and approaches for all students, which often leads to practical implementation remaining at the level of mere inclusion with no changes to the support system.

It follows from this source’s that an inclusive policy is officially supported and developed in China, but its implementation in practice is uneven due to a number of limitations, including insufficient teacher training and inconsistencies between regulatory documents and actual requirements in educational institutions. The main problems include insufficient adaptive environment and consideration of cultural and social factors affecting the perception of inclusivity.

In the Kazakh scientific literature, it was also possible to discover several prominent authors and perspectives that delve into different facets of inclusive education.

The study by Tatarchuk and Tynyshtyk examines the abilities of teachers and the real difficulties they face in teaching children with special educational needs in regular schools in Kazakhstan[4].

The study notes that the majority of teachers are positive about the idea of inclusive education. However, there are problems in the professional training of teachers, as well as a lack of methodological materials and weak institutional support, which makes it difficult to effectively implement inclusive practices.

In their work published in 2025, Chakanova and Myrzakhanova analyze the difficulties faced by foreign language teachers in implementing an inclusive approach. They note that there are a number of problems, such as a lack of trained teachers, a lack of specialized materials, and a lack of resources for adaptation[5].

The authors propose specific solutions, such as regular teacher training and collaboration with experts in the field.

Another significant contribution to the development of integration theory and practice in Kazakhstan was the work of Altynai Kalieva. In her research, she conducted an in-depth analysis of educational policy and obstacles faced by government strategies[6].

Kaliyeva emphasizes the importance of developing a conceptual framework and finding more flexible and effective solutions for the implementation of inclusive education in the multinational educational space of the country.

According to these authors, there are a number of problems in Kazakhstan that need to be solved. Among them are insufficient qualifications of teachers, difficulties in managing changes, lack of adapted materials and weak support for the implementation of educational strategies.

The authors propose solutions to these problems, similar to those proposed in studies conducted in China. In particular, they propose to improve the professional training of teachers, develop infrastructure and create more effective mechanisms of state support.

In scientific research conducted in China and Kazakhstan, inclusive education is seen as a temporary tool that ensures equal access to education for children with special educational needs. However, there are approaches and practices for implementing inclusive education.

In Chinese studies, such as the work of Jiezhen and Wang Qian Fu, it is noted that inclusive education is officially enshrined in state educational policy and implemented through models of inclusion of children with disabilities in regular classes. However, the authors note that in practice, inclusive education often remains formal.

The main problems include limited adaptation of the educational environment, the gap between regulatory documents and the existing situation, as well as insufficient development of classification systems, infrastructure, school and adaptation programs, curricula and teacher training.

Research conducted in Kazakhstan by Tatarchuk and Tynyshtyk, Chakanova and Myrzakhanova, and Altynai Kalieva focuses on the potential and support for inclusivity among educators and educational institutions.

Significant obstacles to improving the effectiveness of education have been identified, such as insufficient teacher training, limited methodological and adapted scientific materials, weak institutional support and insufficient infrastructure.

The authors propose vocational training, improved program support, and the creation of more flexible inclusion mechanisms in schools.

A comparative analysis shows that in China the problem lies in the inconsistency of practice with regulatory requirements and limited adaptation of the educational environment. In Kazakhstan, the main difficulties arise with staff training, availability of materials, and organizational support at the school and regional levels.

In more remote countries, there is a serious need to develop professional teacher training, upgrade academic programs, provide employment, and strengthen institutional support.

Unlike in China, where the emphasis is on formal inclusion in classes, in Kazakhstan it is more important to create conditions for an inclusive environment. This requires comprehensive changes at the level of the current process and educational policy.

The conclusion is that despite the differences in approaches, both contexts demonstrate that the existence of a regulatory framework and government support is not a guarantee of effective implementation of inclusive education. China demonstrates broad institutional support, but faces limited practical adaptation. At the same time, Kazakhstan has potential in the field of pedagogical methodology, but faces a lack of resources and methodological support.

For both countries, it is necessary to develop comprehensive strategies, combine teacher training, adapt school curricula and provide infrastructural support so that inclusive education can work not only formally, but also actually in school practice.

Research methodology

The theoretical and analytical method is used to study the regulatory framework, conceptual foundations and theoretical aspects of inclusive education in China and Kazakhstan. This method provides a systematic analysis of scientific and regulatory sources, including works by Chinese authors (Wu Jiezhen, Wangqian Fu) and Kazakhstani researchers (Tatarchuk and Tynyshtyk, Chakanova and Myrzakhanova, Altynay Kalieva), as well as government concepts and strategies for the development of inclusive education. This method allows us to identify key trends, strengths and weaknesses of inclusive education models, existing problems and ways to solve them, as well as to form a comprehensive understanding of the principles, approaches and mechanisms of inclusive education in the two countries.. The use of the theoretical and analytical method makes it possible to systematize data taking into account national characteristics, identify common features and differences, and justify the need to use a comparative approach to analyze the effectiveness of practical models of inclusive education.

A comparative analysis of the experience of China and Kazakhstan in the field of inclusive education reveals similarities, differences and opportunities for adapting successful practices.

Within the framework of this method, comparison criteria are selected, such as the regulatory framework, organizational structure, teacher training, curriculum adaptation, infrastructure and forms of support for children with special educational needs.

The data is systematized and compared, which makes it possible to identify the strengths of each model and the factors limiting the effectiveness of inclusive education.

Based on the analysis, practical recommendations are being formed on adapting national experience to improve the quality and accessibility of inclusive education. Comparative analysis is an effective research tool that allows us to assess the impact of different approaches on the quality of the educational process and develop proposals for improving the practice of inclusive education in both countries.

The combination of the theoretical and analytical method and comparative analysis provides an integrated approach to research, combining the study of theoretical and normative foundations with a practical comparison of national models of inclusive education. This allows us not only to identify existing problems, but also to formulate recommendations for their solution.

Results and discussion

The theoretical and analytical approach makes it possible to organize and understand information from official documents and scientific papers, identifying the main directions, successes and difficulties that characterize the development of inclusive education in each state.

Using this method, it was revealed that inclusive education in China is developing as part of a special education policy focused on Learning in Regular Classrooms, a model for teaching children with special needs in regular schools. However, terminology in research often overlaps with “integration” and “special education” which creates conceptual heterogeneity and makes it difficult to form a unified theory of inclusion[7].

An analysis of literary sources shows that the research conducted in China in recent decades has been systematized into a separate field. However, research interests in this area remain heterogeneous: the greatest attention is paid to visual impairments and research in the university environment, while other groups of special educational needs are insufficiently studied.

A number of studies emphasize that there is a gap between the proclaimed rights of children to inclusive education and their actual access. There is an uneven distribution of resources, insufficient training of general school teachers, and limited practical support for teachers and families, which hinders quality inclusion[8].

The study demonstrates that, despite the government's efforts to expand learning opportunities, the quality of involvement in the educational process can vary and depends on the qualifications of teachers, as well as on the availability of methodological materials, and not only on the availability of education[9].

Thus, the theoretical and analytical method revealed that China has a strong regulatory framework and policy goals, but faces difficulties in implementing and developing a unified theoretical framework for inclusion.

In the Republic of Kazakhstan, inclusive education is enshrined in legislative acts, including the Law "On Education" and strategic development plans. The legal framework continues to evolve towards ensuring equal opportunities for all[10].

Research shows that teachers in Kazakhstan, as a rule, support the concept of inclusive education, see its benefits for the social development of children, but face limited opportunities for professional growth and a lack of adapted teaching materials[11].

The study shows that lack of resources, weak cooperation between educational institutions and families, insufficient supervision by school management and lack of organized assistance hinder the effective implementation of inclusive education[12].

As a result of the theoretical analysis, data were obtained that allow for a comparative analysis. The identified features, advantages and disadvantages, key trends, obstacles and prospects of each country provide the necessary information for comparison.

Thus, a study of Chinese sources has shown that the country has a solid legislative framework and institutional support, but there are problems with practical adaptation and teacher training. Research in Kazakhstan has shown that the teaching community is ready to introduce inclusive education, but faces limitations in resources and institutional support. This provides an opportunity not only to identify successful practices, but also to identify problematic aspects that can be used to improve inclusive education in both countries(table 1).

Table 1 – Comparative SWOT analysis of inclusive education systems in China and Kazakhstan

Strenghts	**Weaknesses**
In China, there is a well-developed regulatory framework and the systematic inclusion of inclusion in educational policy (LRC orientation and equality policy). A large amount of research and active academic attention to the topic. *In Kazakhstan,* Legislative support and government development programs. The positive attitude of many educators towards the idea of inclusion	*In China,* The gap between policy and practice; insufficient practical adaptation. Lack of general school teacher training. *In Kazakhstan,* Limited professional training and advanced training for teachers. Lack of adapted materials and resources.
Opportunities	**Threats**
In China, The opportunity to develop international cooperation and exchange experience. Using technology to support inclusion *In Kazakhstan,*	*In China,* Improving the quality of an inclusive environment through enhanced teacher training. Integration of assistive technologies and interdisciplinary approaches. *In Kazakhstan,* Social stereotypes and insufficient public support. Insufficient institutional coordination.

The source was compiled by the author on the data [13-16]

The research, conducted using a theoretical and analytical approach, allowed for a deep study of the fundamental principles, legislative framework and scientific approaches to the development of inclusive education in China and Kazakhstan.

An analysis of scientific papers and government documents has shown that in both countries inclusive education is officially recognized as one of the key areas of educational policy and is considered as a tool to ensure equal access to education for children with special educational needs.

The analysis also showed that the presence of regulatory guidelines does not always lead to their effective implementation in practice. This indicates a gap between the stated goals and the actual working conditions of educational organizations.

As a result of theoretical and analytical research, the main directions of the development of inclusive education have been identified. China has seen the steady formation of inclusive practices at the institutional

level, the active development of a model for teaching children with special needs in regular classrooms, and significant attention from the government and the scientific community to this topic.

One of the advantages of the Chinese model is the systemic nature of education policy and the widespread adoption of inclusive approaches. However, significant shortcomings were also found, such as insufficient adaptation of curricula, limited teacher training in regular schools, and uneven allocation of resources, which negatively affects the quality of inclusive practice.

In the Republic of Kazakhstan, the application of a theoretical and analytical approach has made it possible to determine that inclusive education is actively developing as part of the modernization of the national education system and meets international standards.

Among the advantages of the Kazakh model, one can note the positive attitude of teachers towards the idea of inclusion and the availability of a legislative framework that supports the education of children with special educational needs in regular schools.

The study also revealed shortcomings. Among them are insufficient professional training of teachers, lack of adapted educational materials, limited resources and insufficient coordination between educational institutions and other social institutions.

The results obtained during the theoretical and analytical research became the basis for a comparative analysis. Among other things, SWOT analysis elements were used, which allowed structuring the identified strengths and weaknesses, as well as opportunities and threats for the development of inclusive education in both countries.

A comparative analysis showed that China and Kazakhstan have common features, such as regulatory recognition of inclusion and the desire to expand access to education. However, they differ in the nature and depth of the implementation of inclusive practices.

China has a more developed institutional and political structure, but there are problems with the practical adaptation and conceptual integrity of inclusion. In Kazakhstan, inclusive practice is formed at the school level, but there are social barriers, lack of resources and weak institutional support.

The application of a theoretical and analytical approach and comparative analysis has revealed both general trends and unique features of the development of inclusive education in China and Kazakhstan.

These methods have demonstrated that the effectiveness of inclusive education depends not only on the availability of a legislative framework, but also on the level of teacher training, adaptation of the educational environment, availability of resources and social attitudes.

The results of the study provide the foundation for future research and the development of practical advice aimed at improving national models of inclusive education and adapting successful elements of foreign experience.

Conclusion

This research is a contribution to the theoretical and practical understanding of the development of inclusive education, analyzing its features in the context of China and Kazakhstan. First of all, it allows us to systematize and summarize existing scientific approaches to inclusive education in these countries, identifying common trends and specific features due to differences in educational policy, institutional structure and socio-cultural context.

From a theoretical point of view, the study is an in-depth analysis of inclusive education as a complex socio-pedagogical phenomenon. It demonstrates that the effectiveness of inclusive education is determined not only by regulatory and legal regulation, but also by the actual conditions of implementation, such as the level of teacher training, adaptation of the educational environment and social attitudes.

A comparative analysis of the experience of China and Kazakhstan makes it possible to expand the theoretical base of comparative pedagogical research and identify the factors influencing the success of inclusive models in various national contexts.

From a practical point of view, the study provides a basis for making managerial and pedagogical decisions.

The identified strengths and weaknesses of national inclusive education systems can be used by educational authorities and educational organizations in developing and adjusting programs for the development of inclusive education, planning teacher training and improving support mechanisms for students with special educational needs.

The results of the study show which elements of foreign experience can be adapted to national conditions, which increases the applied value of the work.

The study also performs a diagnostic function, as it allows us to identify existing barriers to the implementation of inclusive education and identify problem areas that require priority attention. This creates the basis for further empirical research and the development of more targeted educational strategies.

Thus, this study provides a scientifically sound understanding of the state and prospects for the development of inclusive education. It promotes the integration of theoretical knowledge and practical conclusions, as well as forms the basis for further research and improvement of educational policy in the field of inclusion.

References

1. Makoelle T. M., Somerton M. Inclusive Education in a Post-Soviet Context. – Springer International Publishing, 2021.
2. W. Jiezhen. Inclusive education in modern Chinese society: a sociological analysis//Society: sociology, psychology, Pedagogy. 2024. No. 7. URL: https://cyberleninka.ru/article/n/inklyuzivnoe-obrazovanie-v-sovremennom-kitayskom-obschestve-sotsiologicheskiy-analiz (accessed 02.01.2026).
3. Wangqian Fu. Inclusive education in China . – Routledge,2022. – P. 325
4. Tatarchuk K. S., Tynyshtyk A. E. Inclusive education in kazakhstan: examining the challenges and opportunities //Scientific Results. – 2026. – №. 12.
5. Chakanova A., Myrzakhanova D. Inclusive Education: Challenges and Solutions for Language Teachers //Foundations and Trends in Modern Learning. – 2025. – №. 11.
6. Kaliyeva A. Educational Policy and Multicultural Environment: Establishing Inclusive Educational Systems in Kazakhstan//Publisher. agency: Proceedings of the 7th International Scientific Conference «Theoretical Hypotheses and Empirical results»(July 11-12, 2024). Oslo, Norway, 2024. 203p. – 2024. – P. 22.
7. Wu K. Research on inclusive education in China from 1999 to 2024: A scientometric analysis //Social Sciences & Humanities Open. – 2025. – T. 12. – P. 101982.
8. McCabe H. et al. Inclusive education in China: From policy to implementation to on the ground experiences //Review of Disability Studies: An International Journal. – 2024. – T. 18. – №. 4.
9. Yang Y. et al. Chinese pre-service general education teachers' attitudes and self-efficacy toward inclusive education //Frontiers in Psychology. – 2025. – T. 16. – P. 1490144.
10. Alipbek A. Z. et. all The current state of inclusive education in the Republic of Kazakhstan //International Journal of Humanities and Natural Sciences. – 2023. – №. 5-4 (80). – P. 78-82.
11. Beisembayeva D. D. Prerequisites and regulatory framework of inclusive education in the Republic of Kazakhstan //USNTU Bulletin. Science, education, economics. Series: Economics. – 2015. – №. 3 (13). – P. 19-21.
12. Bilyalov D. et al. Barriers To Inclusion: Insights from Special Education Teachers in Kazakhstan //Eurasian Journal of Educational Research (EJER). – 2024. – №. 113
13. Zhang C., Miao X. Systematic Review on Chinese Special Education and Inclusive Education: China's Solution in Globalization //ECNU Review of Education. – 2025. – T. 8. – №. 4. – P. 937-964.
14. Qu X. A critical realist model of inclusive education for children with special educational needs and/or disabilities //International Journal of Inclusive Education. – 2022. – T. 26. – №. 10. – P. 1008-1022.
15. Maulsharif M., Nurbekova Z., Naimanova D. The Path to Inclusive Education in Kazakhstan: Barriers to Overcome //Eurasian Journal of Educational Research (EJER). – 2022. – №. 99.
16. Abdizhamalova A., Tulekova G., Antikeyeva S. Implementing inclusive education in Kazakhstan: objective needs and real options //Scientific Collection «InterConf+». – 2023. – №. 39. – P. 113-119.

TEACHERS' DIGITAL COMPETENCE AND ITS ROLE IN EFFECTIVE TECHNOLOGY INTEGRATION IN EFL CLASSROOMS

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Abstract

This study explores the relationship between teachers' digital competence and the effectiveness of technology integration in English as a Foreign Language (EFL) classrooms. In the context of rapid educational digitalization, digital competence has become a core pedagogical requirement rather than an auxiliary skill. Adopting a descriptive mixed-methods approach, the study examines EFL teachers' self-perceived digital competence, their use of digital tools in instructional practice, and the contextual factors influencing technology-mediated teaching. The findings suggest that contemporary EFL teachers demonstrate high levels of digital self-efficacy and actively employ a wide range of digital and AI-supported tools to enhance learner engagement, autonomy, and collaborative interaction. At the same time, the study identifies persistent systemic challenges that limit the full pedagogical potential of technology integration, including infrastructural constraints, time pressure, and insufficient institutional support. The results highlight a critical gap between individual teacher competence and institutional readiness, underscoring the need for professional development models that prioritize pedagogical alignment, ethical use of artificial intelligence, and sustained organizational support for technology-enhanced EFL instruction.

Keywords: teacher digital competence; technology integration; EFL classroom; digital pedagogy; artificial intelligence in education; teacher self-efficacy; institutional support; learner autonomy; professional development; educational technology; systemic barriers; digital transformation

I. Introduction

In the contemporary era, the mastery of digital competencies has emerged as a fundamental prerequisite for educators striving to cultivate productive and immersive instructional settings. Given the relentless progression of educational technologies, practitioners of English as a Foreign Language (EFL) are under heightened pressure to incorporate electronic resources that foster communicative proficiency, creative expression, and collaborative inquiry within the learning environment. This transition toward technologically mediated pedagogy has fundamentally altered conventional instructional frameworks, underscoring the necessity for a synthesis of pedagogical content knowledge and digital fluency.

Notwithstanding the burgeoning prioritization of digital modalities, a significant portion of the teaching workforce encounters persistent obstacles regarding the efficacious application of these tools. Current practices often reveal that technological implementation is restricted to rudimentary functions like digitized presentations or automated assessments, thereby failing to leverage such resources for the stimulation of active learning or authentic linguistic exchange. This phenomenon exemplifies a critical tension within modern educational discourse: the divergence between the ubiquity of digital infrastructure and the professional capacity to utilize these assets for meaningful language acquisition. Although a consensus exists regarding the utility of digital innovations, a disparity remains in the levels of self-efficacy and preparedness required to implement them in a manner that substantively elevates student achievement and involvement.

The present inquiry investigates the impact of educator digital proficiency on the quality of technological integration within EFL contexts. The research focuses on analyzing instructional perceptions of digital capabilities, the prevalence of specific technological applications, and the subsequent influence of these competencies on classroom practice. Through this investigation, the study endeavors to elucidate the correlation between digital literacy and the realization of successful, technology-enhanced pedagogical strategies.

The present study is guided by the following **research questions**:

– To what extent do EFL practitioners perceive their individual levels of digital competence within the framework of modern pedagogical requirements?

– Which specific digital instruments and instructional practices are most frequently utilized by educators within the EFL classroom environment?

– In what ways does the digital proficiency of teachers dictate the efficacy and quality of technology-mediated integration during language instruction?

By addressing these questions, this article contributes to understanding the evolving role of teachers in the digital age and offers insights into how digital competence can support more effective, engaging, and learner-centered EFL instruction.

II. Literature review

The rapid evolution of technological innovation has fundamentally restructured the educational landscape of the twenty-first century, establishing digital proficiency as a foundational skill for both instructors and students. Within this contemporary paradigm, the educator's role has shifted from a traditional purveyor of information to a facilitator who orchestrates, directs, and evaluates learning within digitized environments. Consequently, the incorporation of digital instruments into English as a Foreign Language (EFL) settings has emerged as a primary metric for instructional excellence and pedagogical modernization. Successful implementation necessitates that educator possess not only technical dexterity but also the pedagogical discernment required to align digital assets with specific linguistic objectives.

Digital competence represents a multifaceted construct that transcends rudimentary computer literacy, involving the creative, critical, and ethical application of technology in professional spheres. Falloon (2020) conceptualizes teacher digital competence as the convergence of technological, pedagogical, and content knowledge, which empowers educators to cultivate substantive learning experiences. This proficiency demands an adaptable approach to tool selection based on classroom dynamics and the cognitive or emotional requirements of the learners. Corroborating this view, Ağaoğlu and Demir (2020) posit that twenty-first-century attributes, which include critical inquiry, problem-solving, and collaborative engagement, must be systematically integrated into pedagogical frameworks. Viewed through this lens, digital competence is not a peripheral technical skill but a cornerstone of contemporary instructional practice.

This heightened expectation for digital fluency reflects a global transition toward learner-centered methodologies that prioritize authenticity and interactive engagement. In this framework, digital competence acts as the nexus between technological advancement and pedagogical intent, transitioning technology from a medium for content delivery to a vehicle for communication and creativity.

The efficacy of technological integration is predicated less on the availability of hardware and more on the strategic application of these resources to bolster language acquisition. Nurhidayat et al. (2024) assert that digital competence is the primary determinant of whether technology adds value to the instructional process. Their research indicates that educators possessing advanced digital skills are more inclined to develop interactive curricula, utilize authentic digital corpora, and foster collaborative environments. Conversely, a lack of proficiency often results in a reliance on passive, presentation-centric models that fail to capitalize on the communicative potential of digital tools.

Further expanding on this, Gönen (2019) utilizes a qualitative analysis of situated integration to demonstrate that success is heavily influenced by systemic factors, including institutional infrastructure and reflective practice. The findings suggest that optimal integration occurs when practitioners dynamically calibrate digital activities to meet student needs, thereby embedding technology into the core of instructional design. Additionally, Muhammad (2020) illustrates that online media can significantly enhance learner agency and motivation. This research suggests that while digital platforms can encourage self-regulation and peer-to-peer interaction, the realization of student autonomy remains contingent upon the teacher's managerial and pedagogical guidance.

Despite the recognized advantages of digital integration, the attainment of high-level competence is often obstructed by professional and systemic hurdles. Factors such as temporal constraints, inadequate institutional training, and disparate access to digital resources frequently impede effective implementation (Gönen, 2019; Nurhidayat et al., 2024). Furthermore, a "competence gap" exists where educators may be familiar with digital tools but lack the confidence to design tasks that satisfy complex communicative and cognitive goals, leading to superficial usage.

To mitigate these issues, current scholarship advocates for professional development that emphasizes pedagogical synthesis over mere technical instruction. Ağaoğlu and Demir (2020) stress the need for training that enables teachers to support language outcomes through collaborative digital tasks. Similarly, Falloon (2020) argues for a focus on the ethical and reflective dimensions of technology, ensuring educators can critically assess digital content and model responsible usage.

In conclusion, the extant literature highlights that educator digital competence is an indispensable element of successful technology integration in EFL contexts. Proficient educators do not merely adopt tools; they transmute them into pedagogical instruments that facilitate autonomy and creativity. However, the realization of this potential is dependent upon sustained professional evolution and institutional support. While the importance of this competence is widely acknowledged, the specific relationship between an educator's self-perceived skills and their actual classroom application remains insufficiently examined. This scholarly lacuna necessitates the empirical investigation undertaken in this study, which seeks to determine how digital proficiency shapes the overall quality of technology-enhanced language pedagogy.

III. Methodology

The present study adopted a descriptive mixed-methods approach to investigate the nexus between EFL practitioners' digital competence and the efficacy of technological integration. By utilizing both quantitative and qualitative data streams, the research sought to provide a comprehensive analysis of current instructional practices, levels of professional self-efficacy, and the systemic challenges inherent in digital pedagogy.

The study involved a cohort of 12 in-service EFL educators (N=12) representing a diverse cross-section of the academic landscape, including state and private secondary schools, language centers, and higher education institutions. Participants were selected via convenience sampling, targeting educators with varying degrees of professional experience.

As illustrated in the demographic data, the sample reflects a predominantly seasoned workforce:

Experience	The majority of respondents (approx. 58%) possessed 6-10 years of experience, while the remaining participants were distributed across the 0-2 and 3-5 year brackets.
Institutional Affiliation	A significant portion of the sample (50%) operated within language centers, with the remainder distributed among universities and primary/secondary schools.

Data were elicited through a structured digital survey administered via Google Forms. The instrument was meticulously designed to progress from demographic profiling to nuanced reflections on pedagogical practice. The survey comprised three primary modules:

- **Section A - Demographic and Professional Profiling.** This section established the participants' professional background and their initial self-assessment of digital proficiency.
- **Section B - Digital Competence and Self-Efficacy.** Utilizing a 5-point Likert scale (ranging from "Strongly Disagree" to "Strongly Agree"), this module evaluated five critical dimensions: instructional confidence, task design capability, formative assessment practices, frequency of technical disruptions, and perceived institutional support.
- **Section C - Qualitative Reflections and Usage Patterns.** This final section employed multiple-choice questions to identify the most prevalent digital tools and barriers. Crucially, it included three open-ended prompts designed to capture qualitative insights into successful pedagogical interventions, professional development requirements, and perceived systemic obstacles.

The survey was disseminated electronically through professional networks on WhatsApp, Telegram, and email. The data collection phase occurred over a seven-day period, from October 2 to October 9, 2025. To ensure ethical rigor, all participants were provided with a plain-language statement outlining the study's objectives. Informed consent was obtained from all respondents, with explicit assurances regarding anonymity and data confidentiality, as results were utilized exclusively for scholarly purposes.

The study utilized a triangulated analytical framework to interpret the findings:

- **Quantitative Analysis:** Data derived from closed-ended and Likert-scale items were processed using descriptive statistics. Frequencies and percentages were calculated to identify central tendencies in tool utilization, levels of confidence, and the prevalence of institutional support.
- **Qualitative Analysis:** Responses from the open-ended queries underwent thematic content analysis. This involved an inductive coding process where individual teacher narratives were categorized into overarching themes, such as student engagement, pedagogical alignment, infrastructure limitations, and ethical considerations in AI.

By synthesizing numerical trends with thematic narratives, the methodology allowed for a robust exploration of how digital competence manifests in the practical realities of the EFL classroom.

IV. Results

The following section presents the findings derived from the survey of 12 EFL participants. The data explores the intersection of professional experience, self-perceived digital competence, tool utilization, and the systemic barriers encountered during technology integration.

Table 4.1: Self-Rated Digital Proficiency and Confidence

Metric	Highest Responses / Mean Indicators
High Digital Skills (Self-Rated)	100% (12 out of 12 respondents)
Instructional Confidence (Likert 5)	83.3% (Strongly Agree)
Pedagogical Alignment (Likert 5)	83.3% (Strongly Agree)
Formative Assessment Usage (Likert 5)	66.7% (Strongly Agree)

The initial data set highlights a high level of self-efficacy among the participants; despite varying degrees of professional experience, the majority of respondents perceive their digital proficiency as a core strength. This indicates a robust sense of digital agency among the cohort, as all 12 participants identified their skill levels as "High." Furthermore, a significant majority (83.3%) expressed maximum confidence in both the technical operation of digital tools and the more complex task of designing pedagogical activities that align technology with specific language learning outcomes.

Table 4.2: Frequency of Digital Tool and Platform Usage

Tool / Platform Category	Frequency of Selection (N=12)	Percentage
Communication & Video (Zoom, Teams, Messaging)	12	100%
AI Tools (ChatGPT, Grammarly)	12	100%
Video Content (YouTube, Vimeo)	12	100%
Gamification (Kahoot, Quizizz, Quizlet)	11	91.7%
Productivity & LMS (Google Suite, Moodle)	10	83.3%
Interactive Lessons (Edpuzzle, Nearpod)	9	75.0%
Collaboration (Padlet, Miro, Jamboard)	8	66.7%

Participants were asked to identify the platforms they employ most frequently, and the results reveal a heavy reliance on communication-based and AI-driven tools. The usage patterns show a universal adoption (100%) of Artificial Intelligence and video conferencing platforms. This shift suggests that digital integration is no longer viewed as a supplementary or "extra" activity, but has become central to the modern EFL instructional framework, prioritizing real-time interaction and automated linguistic support.

Table 4.3: Identified Barriers to Technology Integration

Barrier Type	Frequency of Selection	Percentage
Unstable Internet / Lack of Hardware	11	91.7%
Insufficient Preparation Time	11	91.7%
Lack of Institutional Training	11	91.7%

Despite the high levels of personal competence reported in Table 1, several external factors continue to impede the seamless application of technology in the classroom. The data illustrates a significant "structural-pedagogical gap": while the teachers feel personally competent and motivated, 91.7% of them are concurrently hindered by external constraints such as inadequate infrastructure, severe time pressure, and a lack of specialized institutional training. This suggests that teacher proficiency alone cannot guarantee successful integration if the surrounding environment is unsupportive.

Table 4.4: Thematic Summary of Successful Technology Integration

Pedagogical Theme	Exemplary Tools Used	Observed Impact on Learners
Engagement & Retention	"Kahoot, Quizizz"	Increased competitive motivation and vocabulary recall.
Cognitive Scaffolding	"Edpuzzle, Jamboard"	Improved comprehension through interactive visual aids.
Collaborative Writing	"Padlet, Canva, MS Teams"	Enhanced peer feedback and authentic communication.
Learner Autonomy	"ChatGPT, Flipgrid"	Facilitated self-directed brainstorming and self-correction.

The open-ended responses provided concrete examples of how digital competence translates into classroom success, allowing for qualitative reflections to be categorized by the primary pedagogical benefit observed. The data suggests that when digital competence is high, teachers move beyond simple "substitution" (using a screen instead of paper) and toward "redefinition" (creating tasks that would be impossible without technology). For instance, Teacher 12 noted that using ChatGPT for brainstorming allowed weaker learners to participate on equal footing with their peers, while Teacher 3 observed that MS Teams breakout rooms encouraged shy students to speak more freely than in traditional, face-to-face settings.

The findings demonstrate a high correlation between teacher confidence and the variety of digital tools employed. However, the data also reveals that digital competence alone is insufficient for success; institutional support and infrastructure remain critical variables that dictate whether technology integration is consistent or superficial.

V. Disscussion

The findings of this study provide a nuanced understanding of the relationship between teacher digital competence and the practical realities of the EFL classroom. By synthesizing the quantitative trends and qualitative narratives with existing literature, the following discussion explores how proficiency, tool selection, and systemic barriers intersect to shape modern language instruction.

A primary finding of this research is the remarkably high level of self-perceived digital competence among participants. Unlike earlier studies that often cited teacher hesitation as a primary barrier, 100% of the surveyed educators rated their skills as "High." This shift aligns with Falloon's (2020) Teacher Digital Competency (TDC) framework, which emphasizes the convergence of technological and pedagogical knowledge. The participants in this study demonstrated not just technical fluency, but a high degree of "pedagogical alignment" - the ability to design tasks where technology serves specific linguistic goals. This suggests that the "confidence gap" identified in previous decades is narrowing, as educators increasingly view digital proficiency as an inseparable component of their professional identity.

The universal adoption of AI tools (100%) and video conferencing (100%) highlights a transition toward what the SAMR model describes as "Redefinition." As noted in the results, teachers are utilizing ChatGPT and interactive platforms like Padlet not merely to digitize traditional tasks, but to create entirely new learning opportunities. This corroborates Muhammad's (2020) findings that online media can significantly bolster learner autonomy. For instance, the use of AI for brainstorming (Teacher 12) and breakout rooms for speaking practice (Teacher 3) illustrates how digital tools can lower the "affective filter" for shy or weaker learners, fostering a more inclusive and egalitarian classroom environment. This move toward learner-centeredness reflects the broader educational transformation discussed by Ağaoğlu and Demir (2020).

Despite the high digital agency reported by participants, a significant paradox emerges when examining the barriers to integration. While teachers feel competent, 91.7% remain hampered by unstable infrastructure and a lack of institutional support. This "structural-pedagogical gap" validates the concerns raised by Nurhidayat et al. (2024) and Gönen (2019), who argued that digital competence is not an isolated skill but one deeply dependent on contextual factors. The high frequency of technical disruptions reported (91.7%) suggests that the potential of highly skilled teachers is being throttled by institutional limitations. This finding implies that professional development alone is insufficient; without reliable hardware and "digital coaches" (as requested by Teacher 4), even the most competent educators cannot sustain effective technology-enhanced instruction.

The qualitative data underscores a shift in professional development needs. Participants are moving away from requesting "how-to" sessions for basic software and are instead seeking advanced training in ethical AI usage and task-specific pedagogical design. This shift supports Falloon's (2020) argument that teacher training must focus on the reflective and ethical dimensions of digital competence. As educators navigate the complexities of data privacy and the generation gap between themselves and their students, digital competence is evolving from a technical requirement into a sophisticated form of "digital wisdom" that balances innovation with critical awareness.

Conclusion

The findings of this inquiry confirm that digital competence has transitioned from an elective skill to a cornerstone of professional practice for EFL educators. The study reveals a significant evolution in teacher identity; contemporary practitioners possess high digital self-efficacy and are increasingly adept at moving beyond the mere substitution of traditional tools toward the sophisticated redefinition of pedagogical tasks. This is evidenced by the universal adoption of Artificial Intelligence and collaborative platforms, which have proven instrumental in fostering learner autonomy and reducing communicative anxiety. However, a critical "structural-pedagogical gap" remains, as the high level of individual teacher proficiency is frequently throttled by unstable infrastructure, severe time constraints, and a lack of specialized institutional support.

To bridge this gap, educational policy must pivot from providing basic technical literacy toward fostering a holistic ecosystem of digital innovation. This requires prioritizing robust infrastructure and moving professional development toward the ethical and pedagogical dimensions of technology, such as AI-assisted task design and digital mentorship programs. While the limited sample size of this study necessitates caution regarding generalizability, the data clearly underscores that the future of EFL instruction depends not just on the skills of the teacher, but on the capacity of institutions to match that proficiency with tangible resources. Future research should pursue longitudinal observations to further elucidate the direct correlation between these high-level digital competencies and measurable student learning outcomes.

References

1. O. Ağaoğlu and M. Demir, "The integration of 21 st century skills into education: an evaluation based on an activity example," Journal of Gifted Education and Creativity, vol. 7, no. 3, pp. 105–114, 2020.

2. G. Falloon, "From digital literacy to digital competence: the teacher digital competency (TDC) framework," Educational Technology Research and Development, vol. 68, no. 5, pp. 2449–2472, 2020, doi: 10.1007/s11423-020-09767-4.

3. Nurhidayat, Eka & Mujiyanto, Yan & Yuliasri, Issy & Hartono, Rudi. (2024). Technology integration and teachers' competency in the development of 21st-century learning in EFL classroom. Journal of Education and Learning (EduLearn). 18. 342-349. 10.11591/edulearn.v18i2.21069.

4. S. İ. K. Gönen, "A qualitative study on a situated experience of technology integration: reflections from pre-service teachers and students," Computer Assisted Language Learning, vol. 32, no. 3, pp. 163–189, 2019, doi: 10.1080/09588221.2018.1552974.

5. Muhammad, "Promoting students' autonomy through online learning media in efl class," International Journal of Higher Education, vol. 9, no. 4, pp. 320–331, 2020, doi: 10.5430/ijhe.v9n4p320.

SOCIAL-EMOTIONAL LEARNING AS A FACTOR OF STUDENT WELL-BEING AND TEACHER PROFESSIONAL SUSTAINABILITY

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Abstract

Modern educational systems increasingly recognize that academic achievement alone is insufficient for ensuring the long-term success and well-being of students. Emotional stability, interpersonal skills, self-awareness, and the ability to manage stress have become critical competencies for young people navigating complex social and professional environments. At the same time, teachers face growing emotional and psychological demands, which directly affect their professional sustainability and the quality of educational interaction. This article examines social-emotional learning as an integrated mechanism that supports both student well-being and teacher resilience within the educational process. The study focuses on the role of everyday interactions between teachers and students as a foundation for emotionally safe and supportive learning environments. Rather than viewing emotional development as a separate program or discipline, social-emotional learning is considered a continuous and relational process embedded in daily pedagogical practice. Special attention is given to the idea that student development is inseparable from the emotional condition of educators. When teachers experience chronic stress, overload, and lack of support, their capacity to build trusting relationships with learners is significantly reduced. The article analyzes how emotionally responsive teaching practices contribute to reduced conflict, improved communication, and increased student engagement. At the same time, it highlights the importance of institutional support systems aimed at maintaining teachers' emotional balance, professional motivation, and sense of value within the organization. The interaction between student needs and adult capacities is presented as a dynamic model in which sustainable development becomes possible only through mutual emotional investment. The relevance of social-emotional learning is examined in the context of contemporary educational challenges, including student anxiety, declining motivation, and professional burnout among educators. The article argues that emotionally supportive environments enhance adaptive behavior, encourage responsibility, and strengthen interpersonal trust. The findings emphasize that long-term educational effectiveness depends not on isolated interventions but on consistent human-centered practices that recognize emotions as a central component of learning. As a result, social-emotional learning emerges as a strategic factor in fostering educational sustainability, benefiting both students and teachers within a shared developmental space.

Keywords: emotional regulation, interpersonal trust, psychological safety, educator resilience, student engagement, supportive environment, professional well-being

Introduction

Emotional processes play a fundamental role in shaping how students experience learning, interpret information, and respond to academic demands. Emotions affect attention, memory, and cognitive flexibility, influencing the depth of understanding and the ability to apply knowledge in different contexts. When learners feel emotionally safe and supported, they demonstrate greater openness to new ideas and a higher level of engagement in educational activities.

A supportive emotional climate encourages motivation and persistence, particularly when students encounter difficulties. Positive emotional experiences reduce fear of failure and promote a willingness to participate in discussions, collaborative tasks, and problem-solving activities. In such environments, students are more likely to develop confidence in their abilities and maintain interest in learning. Conversely,

emotionally unsafe or overly rigid settings may lead to stress, avoidance behavior, and decreased academic involvement. Students who experience constant pressure or lack of emotional understanding often struggle with concentration and show reduced academic resilience.

Emotional awareness and regulation are essential for managing academic challenges. The ability to recognize emotions, control impulsive reactions, and respond constructively to stress allows students to remain focused and adaptable. These skills support effective communication and cooperation with peers, contributing to a positive learning atmosphere. As a result, emotional foundations should be viewed as a core element of educational practice rather than an additional component. Creating emotionally supportive conditions enhances not only academic outcomes but also students' long-term capacity for personal and social development.

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Teacher Well-Being and Professional Stability

Teacher well-being is a critical factor in ensuring professional stability and sustained effectiveness in educational institutions. In colleges of Kazakhstan, teachers operate within a rapidly changing educational environment that includes curriculum updates, increased accountability, digitalization of learning processes, and the growing social and emotional needs of students. These conditions place significant emotional and professional demands on educators, often requiring them to perform multiple roles beyond teaching, such as mentoring, counseling, and administrative coordination.

Professional sustainability depends not only on pedagogical competence but also on emotional balance, recognition, and manageable workloads. When teachers experience chronic overload, lack of appreciation, or limited opportunities for professional growth, their emotional resources gradually decline. This may result in reduced motivation, emotional detachment, and decreased instructional quality. In contrast, educators who receive emotional and institutional support demonstrate greater resilience, patience, and adaptability in their teaching practices [2].

In the context of Kazakhstani colleges, supportive organizational cultures play a crucial role in maintaining teacher well-being. Leadership that values open communication, provides constructive feedback, and acknowledges teachers' contributions fosters a sense of professional dignity and psychological safety. Opportunities for peer collaboration, mentoring, and reflective dialogue further strengthen emotional stability and professional confidence. Such environments enable teachers to respond more effectively to student diversity and behavioral challenges.

Supporting teacher well-being has a direct impact on classroom dynamics and student outcomes. Emotionally balanced educators are more capable of establishing trusting relationships, managing conflict constructively, and modeling healthy emotional regulation. Therefore, investing in teacher well-being within Kazakhstan's college system is essential for sustaining professional stability and creating learning environments that promote both academic success and emotional development.

Relational Nature of Educational Interaction

Educational interaction is not limited to the transmission of knowledge; it is fundamentally relational in nature. Learning develops through continuous social exchange in which trust, respect, and emotional responsiveness play a decisive role. In contemporary college education, especially within the context of Kazakhstan, the quality of relationships between teachers and students increasingly determines not only academic outcomes but also students' emotional well-being and engagement.

Trust-based interactions create conditions for open dialogue, where students feel safe to express opinions, ask questions, and share difficulties without fear of judgment. When teachers demonstrate empathy, consistency, and genuine interest in students' experiences, learners are more likely to participate actively and take responsibility for their own learning. Such relationships reduce emotional barriers and support constructive communication, which is particularly important for adolescents and young adults navigating identity development and social challenges [3].

Relational interaction also supports emotional expression and mutual respect. Through respectful dialogue and attentive listening, teachers model effective communication and conflict resolution strategies. This approach fosters a sense of belonging and strengthens students' social competence. In contrast, formal and emotionally distant interactions may lead to disengagement, resistance, and weakened motivation, limiting the educational impact of instruction.

In Kazakhstan's colleges, where students often face academic pressure alongside personal and social transitions, relational pedagogy becomes especially relevant. Strong teacher–student relationships contribute to a positive learning climate, promote psychological safety, and enhance overall educational effectiveness. Therefore, recognizing the relational nature of educational interaction is essential for creating sustainable and human-centered learning environments.

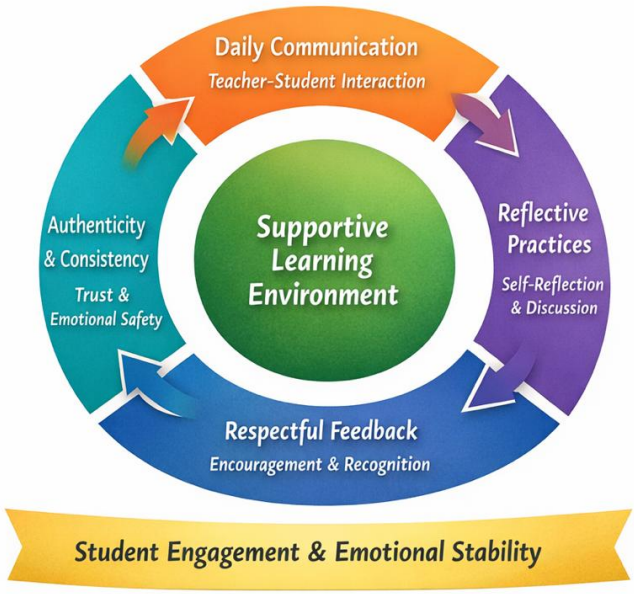
Integration into Daily Practice

Effective social-emotional learning is most sustainable when it is integrated into everyday educational practice rather than implemented as isolated activities or short-term initiatives. Routine communication between teachers and students provides continuous opportunities to develop emotional awareness, empathy, and responsible behavior. Daily interactions, such as classroom discussions, feedback sessions, and informal conversations, serve as natural contexts for strengthening social and emotional competencies.

Reflective dialogue plays a central role in this integration. When teachers encourage students to reflect on their experiences, emotions, and learning challenges, students gradually develop self-awareness and emotional regulation. Short reflective questions, group discussions, and guided conversations help learners connect academic content with personal meaning [4]. Such practices require minimal time but contribute significantly to emotional engagement and mutual understanding.

Respectful and constructive feedback further reinforces social-emotional development. Feedback that acknowledges effort, emotions, and individual progress promotes trust and motivation. In contrast to evaluative or judgment-based responses, supportive feedback encourages students to view mistakes as part of the learning process. Consistency in communication and feedback allows students to form stable expectations and feel psychologically safe within the educational environment.

Authenticity is a key condition for achieving lasting results. Students, particularly at the college level, are sensitive to artificial or formalized approaches [5]. When teachers demonstrate genuine care, emotional openness, and coherence between words and actions, social-emotional learning becomes meaningful and credible. Therefore, integration into daily practice requires not additional workload, but a shift in pedagogical mindset toward relational and emotionally responsive teaching.



Pic. 1. Integration of Social-Emotional Learning into Daily Educational Practice

Conclusions

Social-emotional learning (SEL) functions as a unifying framework that supports both student well-being and teacher professional sustainability. Emotionally responsive interactions enhance trust, reduce stress, and improve engagement without introducing additional academic pressure. When educators intentionally integrate SEL into daily classroom routines, students develop essential skills such as self-awareness, emotional regulation, empathy, and responsible decision-making. These competencies not only contribute to academic success but also foster a positive school climate where collaboration and mutual respect thrive.

Furthermore, sustainable educational development is achieved when the emotional needs of all participants—students, teachers, and staff—are acknowledged and addressed within everyday pedagogical practice. Teachers who model emotional intelligence and apply SEL principles are better equipped to manage classroom challenges, prevent burnout, and maintain professional satisfaction. In this way, SEL serves as a holistic approach that aligns cognitive, social, and emotional growth, ultimately creating an inclusive, supportive, and resilient learning environment.

References

1. Brackett, M. A. (2019). *Permission to Feel*. Celadon Books.
2. Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2020). Implications for educational practice. *Educational Psychologist*, 55(1), 1–16.
3. Jennings, P. A., & Greenberg, M. T. (2009). The prosocial classroom. *Review of Educational Research*, 79(1), 491–525.
4. OECD. (2021). *Beyond Academic Learning*. OECD Publishing.
5. Schonert-Reichl, K. A. (2017). Social and emotional learning and teachers. *Future of Children*, 27(1), 137–155.

EFL LEARNERS' PERCEPTIONS OF SHADOWING-BASED LISTENING INSTRUCTION: A LONGITUDINAL CLASSROOM STUDY

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Abstract

Listening comprehension is a challenging skill for many English as a Foreign Language (EFL) learners, particularly in classroom contexts where listening is often treated as a passive activity. This study investigates learners' perceptions of shadowing-based listening instruction through a four-week longitudinal classroom intervention. A mixed-methods design was employed, combining quantitative data from pre- and post-instruction questionnaires with qualitative data from classroom observations and open-ended learner responses. The participants were 24 secondary school EFL learners at A2-B1 proficiency levels with no prior systematic experience with shadowing. The findings reveal positive perceptual shifts across several dimensions, including increased listening confidence, reduced perceived difficulty, lower listening-related anxiety, and high perceived usefulness of shadowing for maintaining attention. Qualitative evidence supported these trends, showing increased engagement, listening awareness, and emotional comfort over time. The results suggest that shadowing can be effectively integrated into regular EFL listening instruction as a short, guided routine that supports both cognitive and affective aspects of learning.

Keywords: shadowing technique, EFL listening, learner perceptions, listening confidence, listening anxiety, classroom instruction, mixed-methods study

I. Introduction

Listening comprehension is a fundamental skill in English as a Foreign Language (EFL) learning, yet it remains one of the most challenging aspects for learners to develop. Effective listening abilities enable students to access authentic input, engage in meaningful interactions, and build confidence in communicative situations. However, traditional classroom approaches often emphasize receptive listening in isolation, where learners passively listen to input without active engagement or sustained practice opportunities. This can result in limited exposure to natural speech patterns, reduced motivation, and insufficient development of practical listening strategies that transfer to real-world communication contexts.

In response to these limitations, educators have increasingly explored alternative instructional techniques designed to make listening practice more engaging and effective. One such technique that has gained attention in recent years is Shadowing. In this method, learners listen to a spoken input while simultaneously repeating it word-for-word. Research has demonstrated multiple benefits of this approach. Studies show that Shadowing can enhance listening comprehension at elementary and intermediate proficiency levels (Malekmohammad et al., 2024), improve learners' pronunciation and intonation (Hsieh et al., 2013), and contribute to measurable gains in phonemic accuracy, particularly among lower-proficiency learners (Bove & Stewart, 2009). Furthermore, shadowing has been shown to influence psychological dimensions of language learning. Shiota (2012) found that it can increase intrinsic motivation and reduce anxiety in learners previously disengaged from traditional instruction. Additionally, corpus-based analyses have revealed the typical phenomena that emerge during shadowing speech, providing valuable diagnostic information for instruction (Minematsu, 2016).

While these findings are promising, the most exciting research focuses on measurable linguistic outcomes such as pronunciation accuracy, listening comprehension scores, verbal retention rates (Carey, 1971), and reproduction patterns (Shiki et al., 2010) rather than on how learners themselves perceive and experience shadowing-based instruction over an extended period. A longitudinal perspective is particularly valuable because it can reveal how learner perception evolves, whether benefits are sustained over time, and which aspects of shadowing instruction learners find most meaningful or challenging. Additionally, understanding perception

from the learner's viewpoint provides insights into affective factors, engagement patterns, and the practical implementation of shadowing in real classroom contexts.

The present study aims to address this gap by investigating EFL learners' perceptions of shadowing-based listening instruction through a longitudinal classroom study. By tracking learner responses, attitudes, and feedback over multiple weeks, this research seeks to clarify the conditions under which shadowing fosters positive learning experiences and sustained skill development.

This article addresses the following **research questions**:

- How do EFL learners' perceptions of shadowing-based listening instruction change over the course of a longitudinal classroom intervention, and which dimensions of the technique show the most notable shifts?
- What learner-related factors appear to influence positive or negative perceptions of shadowing, and how do these factors interact with instructional design choices?
- What implementation challenges and facilitators emerge when integrating shadowing into classroom practice from learners' perspectives, and how do learner perceptions of these challenges align with observable learning outcomes?

By examining these questions, this article seeks to deepen our understanding of how shadowing can be meaningfully integrated into EFL instruction and to provide evidence-based guidance for practitioners aiming to implement this technique effectively in their classroom.

II. Literature review

Shadowing, as a pedagogical technique in language learning, emerged from simultaneous interpretation practices and has evolved into a recognized methodology for enhancing listening proficiency. Bove and Stewart (2009) provide foundational insights into the utility of shadowing, positioning it as a technique that leverages cognitive mechanisms of attention and phonological processing. Their analysis demonstrates that shadowing transcends mere mechanical repetition, serving as a cognitive tool that realigns learners' attention toward acoustic features that may otherwise be overlooked in conventional listening activities. This reorientation of cognitive resources establishes the theoretical groundwork for understanding why shadowing produces measurable improvements in phonetic and prosodic awareness.

Early empirical investigation into shadowing's efficacy traces back to Carey (1971), whose foundational study examined verbal retention following shadowing versus passive listening conditions. Carey's research revealed that individuals who engaged in shadowing demonstrated superior retention of spoken material compared to those who simply listened passively. This seminal finding established that the motor component of simultaneous repetition, the act of speaking while listening, enhances the encoding and consolidation of linguistic input, a principle that continues to inform contemporary shadowing pedagogy.

The acoustic and suprasegmental dimensions of language learning have been significantly advanced through shadowing-based interventions. Hsieh, Dong, and Wang (2013) investigated the application of the shadowing technique to English intonation instruction among Taiwanese university students. Their experimental design compared shadowing and repetition-only control conditions, revealing statistically significant improvements in the experimental group across multiple pronunciation metrics: intonation (+9 points, $p = 0.000$), word pronunciation (+8 points, $p = 0.002$), fluency (+9 points, $p = 0.001$), and overall pronunciation (+9 points, $p = 0.001$). These findings underscore that shadowing specifically enhances suprasegmental features, such as intonation, stress, and rhythm, which are often neglected in traditional pronunciation instruction.

Complementing this work, Minematsu (2016) conducted a corpus-based analysis of shadowing speech produced by Japanese L2 English learners. Through systematic acoustic analysis of shadowed utterances, Minematsu's research elucidates the micro-level phonological transformations that occur during shadowing practice. The corpus-based approach reveals that learners progressively approximate native speaker prosodic patterns and segmental features through repeated exposure and simultaneous production, suggesting that shadowing creates an optimal feedback loop wherein learners simultaneously perceive and produce target phonological forms.

An important distinction in the shadowing literature concerns methodological variation and comparative efficacy. Shiki, Mori, Kadota, and Yoshida (2010) conducted a detailed comparative analysis examining differences between shadowing and repeating practices. Their investigation revealed critical divergences in the types and rates of reproduced words between the two conditions. Specifically, shadowing resulted in higher reproduction rates of both content and function words, whereas repeating practices, which involve longer delays between stimulus and response, produced different accuracy profiles. This differentiation clarifies that the temporal proximity between input and output in shadowing creates distinct cognitive demands and outcomes, distinguishing it from other repetition-based methodologies and justifying its designation as a discrete pedagogical approach.

Beyond linguistic outcomes, the psychological impact of shadowing warrants examination. Shiota (2012) investigated the effectiveness of shadowing on learner psychology and motivation among Kosen students traditionally instructed through grammar-translation methods. Her research revealed that 62% of respondents reported increased intrinsic motivation following systematic exposure to shadowing-based instruction. Additionally, Shiota documented a 28% reduction in reported anxiety symptoms among participants. These findings suggest that shadowing functions not merely as a cognitive tool for skill development but as a psychologically transformative pedagogical intervention. By shifting instructional paradigms from teacher-centered transmission to active learner engagement, shadowing appears to cultivate affective conditions that facilitate sustained language learning effort.

Recent empirical investigations have documented the direct effects of shadowing on listening comprehension across proficiency levels. Malekmohammad, Salehi, Tabatabaei, and Hashemi Shahraki (2024) examined the effect of shadowing technique on both elementary and intermediate EFL learners' listening comprehension. Their research demonstrated differential outcomes across proficiency bands, revealing that intermediate learners showed more pronounced gains in listening comprehension measures compared to elementary learners. This finding suggests that optimal shadowing efficacy occurs within intermediate proficiency zones, where learners possess sufficient linguistic foundation to benefit from enhanced phonological processing yet remain developmentally positioned to improve decoding automaticity.

Building upon this empirical foundation, Bapir and Faqeabdulla (2025) conducted a rigorous experimental investigation with 20 first-year English majors at Salahaddin University-Erbil using a non-equivalent control group design. Pre-test scores were statistically equivalent between groups (control: $M = 12.35$; experimental: $M = 12.45$), establishing baseline comparability. Post-test results, however, diverged markedly: the shadowing group achieved $M = 20.45$ while the control group reached only $M = 15.25$. Welch's t-test analysis yielded $t(18) = 8.546$, $p = 0.001$, representing a statistically significant and practically substantial effect size. This experimental evidence provides direct empirical validation that systematic shadowing instruction markedly enhances listening comprehension among beginning learners, substantiating the technique's pedagogical utility.

El Moussaoui (2025) synthesized empirical literature spanning 1997-2023 through systematic review methodology, consolidating evidence across 27 studies examining shadowing's effects on bottom-up listening skills. This comprehensive analysis revealed consistent patterns: phoneme perception improves significantly for lower- and intermediate-proficiency learners (effect documented by Hamada, 2015, across 9-session interventions), word recognition accuracy increases substantially (Ginting, 2019), and processing fluency rises across multiple learner populations. Additionally, El Moussaoui's review identified optimal implementation parameters: 4-5 repetitions of level-appropriate material combined with explicit learner instruction yields maximal efficacy. Critically, the systematic review identified significant gaps: long-term retention effects remain underexamined, advanced learner outcomes are inconsistent, and digital implementation tools lack empirical validation. These identified lacunae establish the imperative for research investigating learner perceptions and longitudinal trajectories in shadowing-based instruction.

Despite the growing body of research on the linguistic and cognitive effects of shadowing, relatively little attention has been paid to learners' longitudinal perceptions of shadowing-based instruction in classroom contexts. This gap highlights the need for studies that foreground learner experience alongside instructional implementation.

III. Methodology

The study adopts a longitudinal mixed-methods design to investigate changes in EFL learners' perceptions of shadowing-based listening instruction over time. Both quantitative and qualitative data were collected to obtain a comprehensive understanding of learners' experiences during the instructional intervention. Quantitative data were gathered through pre- and post-instruction questionnaires, while qualitative data were obtained from systematic classroom observation and open-ended learner responses.

The primary focus of the study is on perceptual and affective changes, rather than on objective measurements of listening proficiency or achievement scores. The instructional intervention was conducted over a four-week period, allowing for the observation of developmental trends in learner attitudes, engagement, and perceived effectiveness of shadowing-based listening activities.

Importantly, the study does not aim to measure listening achievement gains. Instead, it seeks to examine how learners perceive, experience, and respond to shadowing-based listening instruction across repeated classroom exposure.

The participants were 24 secondary school EFL learners enrolled in a regular English language course. The learners' proficiency levels ranged from A2 to B1, as determined by institutional placement procedures.

This proficiency range was considered appropriate, as learners at this level possess sufficient lexical and grammatical knowledge to follow spoken input without excessive cognitive overload, while still benefiting from structured listening support.

All participants studied English in a regular classroom context and had no prior systematic experience with the shadowing technique before the study. Participation in the research was voluntary, and learners were informed that the study would not affect their academic assessment.

In this study, shadowing was implemented not as an isolated drill but as a guided listening routine embedded within regular EFL lessons. Instruction was conducted twice a week, with shadowing activities occupying approximately 10-15 minutes per lesson.

Each lesson followed a consistent instructional structure consisting of three stages:

Table 3.1. Instructional Procedure of Shadowing-Based Listening Lessons

Stage	Instructional focus	Description of activities
Pre-listening stage.	Cognitive and linguistic preparation	Learners were prepared for the listening task through topic activation and brief discussion of the listening context. Key vocabulary items were previewed to reduce cognitive load. The teacher provided a short explanation of the purpose and procedure of the shadowing activity to ensure learner awareness of task goals.
Listening and Shadowing stage.	Guided and independent shadowing practice	Learners were first exposed to the audio input without repetition to establish global understanding. During the second exposure, learners engaged in slow-paced guided shadowing supported by teacher modeling and controlled pacing. The third exposure involved normal-paced shadowing, during which learners repeated the input more independently. Shadowing was conducted using both choral and individual modes, with continuous teacher scaffolding throughout the activity.
Post-listening stage.	Reflection and learner feedback	Following the shadowing activity, learners engaged in brief reflection on their listening experience. They were encouraged to comment on perceived difficulty, comfort level, and engagement with the task. Short micro-discussions were occasionally conducted to elicit learner feedback and consolidate listening awareness.

Learner accuracy was not formally assessed during shadowing activities. Instead, the instructor focused on observing learner behavior, engagement patterns, and listening awareness during classroom interaction.

To investigate EFL learners' perceptions of shadowing-based listening instruction, multiple data collection instruments were employed. These instruments were selected to capture both quantitative trends and qualitative insights into learners' experiences over the four-week instructional period. Table 3.2 provides an overview of the instruments used, their purposes, and key features.

Table 3.2. Data Collection Instruments

Instrument	Purpose	Description
Pre-Instruction Questionnaire	To identify baseline learner perceptions	Administered at the beginning of the study to explore learners' initial attitudes toward listening instruction, perceived listening difficulty, confidence and anxiety levels, and expectations regarding listening activities. The questionnaire consisted of Likert-scale items complemented by one to two open-ended questions allowing learners to elaborate on their prior listening experiences.
Classroom Observation	To document classroom behavior and engagement	Conducted throughout the four-week intervention using a non-participant structured observation approach. An observation checklist was employed to record learner engagement, attention during listening tasks, willingness to participate, and indicators of listening awareness such as anticipation and self-correction. Emotional responses, including signs of stress or increased comfort, were also noted. Brief field notes were recorded after each lesson to capture contextual and behavioral nuances.
Post-Instruction Questionnaire	To examine changes in learner perceptions	Administered at the end of the instructional period. The questionnaire included the same core Likert-scale items as the pre-instruction questionnaire to ensure comparability, as well as additional items addressing learners' perceived usefulness of shadowing, changes in comfort over time, and perceived listening improvement. Reflective open-ended questions were included to elicit qualitative insights into learners' experiences with shadowing-based instruction.

Quantitative data from the questionnaires were analyzed using descriptive statistics and pre/post comparisons to identify changes in learners' perceptions over time. Qualitative data from open-ended responses and classroom observation notes were analyzed through thematic analysis, focusing on recurring patterns related to engagement, affective responses, and perceived instructional value.

To enhance the credibility of the findings, data triangulation was employed by comparing self-reported learner perceptions with observed classroom behavior. This approach enabled a more comprehensive interpretation of how learners experienced shadowing-based listening instruction in a real classroom context.

IV. Results

This section presents the findings derived from the longitudinal mixed-methods study, focusing on EFL learners' perceptions of shadowing-based listening instruction over a four-week intervention period. The data analysis combines quantitative insights from pre- and post-instruction questionnaires with qualitative data

gathered through systematic classroom observations and open-ended learner responses, triangulating these perspectives to offer a comprehensive understanding of learners' experiences.

4.1 Quantitative Findings: Pre- and Post-Instruction Questionnaire

A direct comparison of learners' perceptions before and after the shadowing intervention reveals notable shifts across key constructs. Table 4.1 provides an overview of the changes in mean scores for listening confidence, perceived listening difficulty, and listening anxiety/comfort. For constructs where items were reverse-coded (Perceived Difficulty and Listening Anxiety/Comfort), a higher mean score indicates a more positive perception (i.e., less difficulty, less anxiety/greater comfort).

Table 4.1. Comparison of Pre- and Post-Intervention Mean Scores for Perceptual Constructs

Construct	Pre-Intervention Mean (MM)	Post-Intervention Mean (MM)
Listening Confidence	3.1	4.1
Perceived Difficulty	2.9	3.9
Listening Anxiety/Comfort	3.0	3.9

Perceived Difficulty and Listening Anxiety/Comfort scales were reverse-coded, so higher means indicate lower perceived difficulty and lower anxiety (greater comfort), respectively.

4.1.1 Learners' Initial Perceptions (Pre-Instruction Questionnaire)

At the outset of the study, the pre-instruction questionnaire revealed a diverse range of initial perceptions regarding listening in English among the 24 participants.

Table 4.2. Pre-Instruction Responses for Listening Confidence (Q1: "I feel confident when listening to spoken English.")

Response	Number (N=24)	Percentage (%)
Strongly agree (5)	2	8
Agree (4)	6	25
Neutral (3)	9	38
Disagree (2)	5	21
Strongly disagree (1)	2	8
Mean	3.04	

Learners reported a medium level of confidence in their listening abilities, with an overall mean score for the construct of approximately $M = 3.1$ (on a 5-point Likert scale, where 5 indicates "Strongly agree"). As illustrated in Table 4.2 for the item "I feel confident when listening to spoken English," a significant portion of learners expressed a lack of confidence, with 29% disagreeing or strongly disagreeing.

Table 4.3. Pre-Instruction Responses for Perceived Listening Difficulty (Q4: "Listening to English is difficult for me.")

Response	Number (N=24)	Percentage (%)
Strongly agree (5)	7	29
Agree (4)	8	33
Neutral (3)	5	21
Disagree (2)	3	13
Strongly disagree (1)	1	4
Mean (Original)	3.71	
Mean (Reverse-coded)	2.29	

For the construct of perceived listening difficulty, after reverse-coding relevant items (where 1=Strongly agree with difficulty, now 5=Low difficulty), the overall mean score was approximately $M = 2.3$. This initial score suggests a medium-to-high level of perceived difficulty before the intervention. Table 4.3, displaying responses for the item "Listening to English is difficult for me," highlights that 62% of participants originally agreed or strongly agreed with this statement, underscoring that listening was a significant challenge for many.

Table 4.4. Pre-Instruction Responses for Listening Anxiety/Comfort (Q7: "I feel nervous during English listening activities.")

Response	Number (N=24)	Percentage (%)
Strongly agree (5)	5	21
Agree (4)	7	29
Neutral (3)	6	25
Disagree (2)	4	17
Strongly disagree (1)	2	8
Mean (Original)	3.38	
Mean (Reverse-coded)	2.63	

Initial levels of listening anxiety were also noticeable, with the overall mean score for the anxiety/comfort construct, after reverse-coding, being approximately $M = 2.6$. A higher score indicates greater comfort. Table 4.4 illustrates that 50% of participants initially agreed or strongly agreed with the statement "I feel nervous during English listening activities," reflecting a considerable level of apprehension during listening tasks.

Open-ended responses further illuminated these quantitative trends, with several learners expressing concerns about "missing words" or "not understanding fast speech," and others noting a passive role in traditional listening activities. Expectations for new listening instruction were generally positive, though vague, with learners hoping for methods that would make listening "easier" or "more interesting."

4.1.2 Evolution of Perceptions (Post-Instruction Questionnaire)

Following the four-week shadowing intervention, the post-instruction questionnaire revealed significant positive shifts in learners' perceptions.

Table 4.5. Post-Instruction Responses for Listening Confidence (Q1: "I feel confident when listening to spoken English.")

Response	Number (N=24)	Percentage (%)
Strongly agree (5)	9	38
Agree (4)	10	41
Neutral (3)	4	17
Disagree (2)	1	4
Strongly disagree (1)	0	0
Mean	4.13	

Learners' self-reported listening confidence showed a substantial increase, with the overall mean score rising from $M_{pre} = 3.1$ to $M_{post} = 4.1$. As detailed in Table 4.5 for the item "I feel confident when listening to spoken English," the proportion of participants who agreed or strongly agreed rose markedly to 79%, indicating a significant enhancement in their self-efficacy regarding listening.

Table 4.6. Post-Instruction Responses for Perceived Listening Difficulty (Q4: "Listening to English is difficult for me.")

Response	Number (N=24)	Percentage (%)
Strongly agree (5)	1	4
Agree (4)	3	13
Neutral (3)	6	25
Disagree (2)	8	33
Strongly disagree (1)	6	25
Mean (Original)	2.38	
Mean (Reverse-coded)	3.63	

The intervention led to a notable decrease in perceived listening difficulty. The overall mean score for this construct, after reverse-coding, increased from $M_{pre} = 2.3$ *to* $M_{post} = 3.6$. This upward shift signifies that learners perceived listening to English as significantly less difficult. Table 4.6 demonstrates this change for the item "Listening to English is difficult for me," where the number of learners who originally agreed or strongly agreed dropped sharply from 15 to 4.

Table 4.7. Post-Instruction Responses for Listening Anxiety/Comfort (Q7: "I feel nervous during English listening activities.")

Response	Number (N=24)	Percentage (%)
Strongly agree (5)	1	4
Agree (4)	3	13
Neutral (3)	5	21
Disagree (2)	9	38
Strongly disagree (1)	6	25
Mean (Original)	2.33	
Mean (Reverse-coded)	3.67	

A marked reduction in listening anxiety was observed, alongside an increase in perceived comfort. The overall mean score for this construct, after reverse-coding, rose from $M_{pre} = 2.6$ to $M_{post} = 3.7$. This suggests learners felt considerably more relaxed and less stressed. As shown in Table 4.7 for the item "I feel nervous during English listening activities," the number of participants who originally agreed or strongly agreed with feeling nervous decreased from 12 to 4.

Table 4.8. Post-Instruction Responses for Perceived Usefulness of Shadowing (Q10: "Shadowing helps me stay focused during listening activities.")

Response	Number (N=24)	Percentage (%)
Strongly agree (5)	11	46
Agree (4)	9	38
Neutral (3)	3	13
Disagree (2)	1	4
Strongly disagree (1)	0	0
Mean	4.25	

The post-instruction questionnaire included specific items assessing the perceived usefulness of shadowing. The results indicated a strong positive reception of the technique. For the item "Shadowing helps me

stay focused during listening activities," 20 out of 24 participants (84%) agreed or strongly agreed, yielding a high mean score of *M = 4.25*. This demonstrates a clear perception among learners that shadowing positively contributed to their attention and engagement during listening tasks (Table 4.8).

4.2 Learners' Experiences and Behavioral Observations: Qualitative Findings

Qualitative data from systematic classroom observations and open-ended questionnaire responses provided rich insights into the behavioral and emotional aspects of learners' engagement with shadowing, complementing the quantitative findings.

Observations throughout the four-week period revealed a progressive increase in learner engagement. In the initial lessons, participation in choral shadowing was somewhat hesitant, with some learners exhibiting timidity and self-consciousness. However, as the intervention progressed and teacher scaffolding became more routine and familiar, active participation notably increased. Learners appeared more focused during the listening and shadowing stage, often showing signs of anticipating words or correcting their own pronunciation and rhythm during repetition. The transition from choral to individual shadowing, facilitated by the teacher's supportive feedback, was generally well-received, with many learners demonstrating increased confidence in their individual attempts by the final weeks.

Early observations indicated signs of mild stress or frustration, particularly when learners struggled with faster-paced audio or unfamiliar vocabulary. However, these instances were often mitigated by immediate teacher support, repetition, and the gradual increase in comfort levels noted in the questionnaires. By the midpoint of the intervention, learners showed more relaxed postures, increased willingness to try, and fewer visible signs of anxiety. Many open-ended comments highlighted the shift from initial apprehension to a sense of accomplishment. For example, one learner stated, "At first, it felt strange to repeat everything, but now I feel more relaxed and can hear more." Another commented, "It was hard at the beginning, but then it became like a game, and I enjoyed it."

The thematic analysis of open-ended responses identified several recurring themes regarding the perceived benefits and challenges of shadowing:

Enhanced Phonological Awareness. Many learners reported that shadowing helped them "hear sounds better" and distinguish between similar-sounding words and phonemes. Phrases like "I can catch the end of words now" or "it helps me separate words when they speak fast" were common, indicating an improved ability to segment the speech stream. This aligns with the observation of increased listening awareness.

Improved Focus and Attention. Learners frequently commented on how the real-time repetition requirement of shadowing forced them to concentrate more intently on the audio input, preventing their minds from "wandering." This sustained attention was often highlighted as a key benefit, reinforcing the high usefulness rating for focus found in the quantitative data.

Rhythm and Intonation. Several learners specifically mentioned improvements in their perception and imitation of English rhythm and intonation patterns. Comments such as "I understand how the words flow now" and "it helps me speak with the right rhythm" were noted, aligning with observations of more natural-sounding repetitions during later sessions.

Active Listening. The technique was widely perceived as making listening a more active and engaging process, contrasting significantly with previous experiences of passive reception. Learners felt more involved and less like mere recipients of information.

Challenges. Common challenges included keeping up with the speed of native speakers, particularly with rapid or naturalistic speech, and encountering unfamiliar vocabulary, which sometimes disrupted the flow of shadowing. However, many learners also expressed that overcoming these challenges felt rewarding, contributing to their increased confidence and motivation.

4.3 Triangulation of Findings

The triangulation of quantitative and qualitative data revealed a highly consistent and coherent picture of evolving learner perceptions and experiences. The statistically significant increases in perceived usefulness, comfort, and confidence reported in the post-instruction questionnaire were strongly corroborated by observable behaviors in the classroom, such as increased engagement, reduced visible signs of anxiety, and more active, voluntary participation. Learners' open-ended comments directly articulated the specific benefits (e.g., improved phonological awareness, enhanced focus, better rhythm perception) that corresponded to the observed increases in listening awareness and the positive shifts in their Likert-scale responses. This strong congruence between self-reported attitudes and observed behaviors significantly enhances the credibility and robustness of the findings, indicating that learners genuinely experienced positive changes in their perception and engagement with shadowing-based listening instruction within a real classroom context.

V. Discussion

The current findings set out to explore EFL learners' perceptions of shadowing-based listening instruction over a four-week period using a longitudinal mixed-methods design. The findings reveal a consistent pattern of positive perceptual change across multiple dimensions, including listening confidence, perceived difficulty, listening-related anxiety, and perceived instructional usefulness. By triangulating questionnaire data with classroom observation and learner reflections, the study provides a nuanced account of how learners experience shadowing as part of regular listening instruction.

One of the most salient findings of the study is the clear shift in learners' perceptions from moderate confidence and relatively high perceived difficulty toward increased confidence and reduced difficulty following sustained exposure to shadowing-based instruction. These findings align with previous research demonstrating that shadowing supports bottom-up listening processes and improves learners' ability to segment and process spoken input (Minematsu, 2016). However, while earlier studies have primarily emphasized measurable linguistic gains, this investigation extends this line of inquiry by showing that learners themselves become more confident and less anxious as they engage repeatedly in shadowing activities.

The observed reduction in perceived difficulty suggests that shadowing may function as a form of guided attentional training, helping learners cope with fast or continuous speech. As learners become accustomed to synchronizing listening and production, the listening task appears less overwhelming, which is reflected both in self-reported perceptions and observable classroom behavior. This supports the view that listening difficulty is not solely a function of linguistic competence but is also shaped by task design and learner familiarity with listening procedures.

The decrease in listening-related anxiety and the corresponding increase in comfort constitute another important contribution of this study. Prior research has suggested that shadowing can reduce anxiety and increase intrinsic motivation (Shiota, 2012), particularly among learners accustomed to more passive instructional approaches. The present findings corroborate these claims within a secondary school EFL context, demonstrating that learners gradually transition from initial apprehension to greater emotional ease.

Classroom observations provide important insight into this process. Early signs of stress and hesitation were progressively replaced by relaxed participation and willingness to engage, indicating that affective change developed over time rather than immediately. This highlights the importance of a longitudinal perspective: learners' initial discomfort with shadowing should not be interpreted as resistance but as a temporary adjustment phase. As familiarity increases, affective barriers appear to diminish, allowing learners to engage more fully with the listening task.

The qualitative findings further indicate that shadowing promotes active listening and sustained attention. Learners consistently reported improved focus, a finding strongly supported by observational data showing increased anticipation, self-correction, and rhythmic alignment with the audio input. These behaviors suggest heightened listening awareness, which has been identified in previous studies as a key mechanism underlying the effectiveness of shadowing (Shiki et al., 2010).

Importantly, learners did not merely perceive shadowing as helpful for comprehension but described it as transforming listening from a passive activity into an active process. This perception distinguishes shadowing from traditional listening practices and may explain its strong positive reception. The reported improvements in rhythm and intonation perception further reinforce the notion that shadowing facilitates holistic listening engagement, encompassing both segmental and suprasegmental features of speech.

From a pedagogical perspective, the findings suggest that shadowing can be effectively integrated into regular EFL listening instruction as a short, guided routine rather than an isolated drill. The gradual increase in learner comfort and engagement underscores the importance of teacher scaffolding, controlled pacing, and repeated exposure. Teachers should anticipate initial learner difficulty and provide reassurance, emphasizing process over accuracy, particularly in the early stages.

The challenges identified by learners, such as keeping up with fast speech or unfamiliar vocabulary, also point to practical considerations. Appropriate material selection, pacing adjustments, and explicit explanation of shadowing goals may enhance learner experiences and maximize the technique's benefits. Rather than viewing these challenges as limitations, they can be interpreted as productive difficulties that contribute to increased confidence and motivation once overcome.

Despite its contributions, the study has several limitations. The relatively small sample size and the absence of a control group limit the generalizability of the findings. Additionally, the study focused exclusively on learner perceptions and did not include objective measures of listening proficiency. While this focus was intentional, future research could benefit from combining perceptual data with performance-based assessments to explore the relationship between perceived and actual listening improvement.

Further studies might also examine longer instructional periods, different proficiency levels, or digital implementations of shadowing to determine whether similar perceptual patterns emerge. Investigating how

learner perceptions evolve beyond the initial month of instruction would be particularly valuable in understanding the sustainability of shadowing-based listening practices.

Conclusion

This study explored EFL learners' perceptions of shadowing-based listening instruction through a four-week longitudinal classroom investigation employing a mixed-methods design. By focusing on learners' self-reported experiences and observed classroom behavior, the research sought to address a gap in the existing literature, which has predominantly emphasized measurable linguistic outcomes rather than the learner perspective.

The findings demonstrate that sustained exposure to shadowing-based listening activities is associated with positive shifts in learners' perceptions across several key dimensions. Learners reported increased listening confidence, reduced perceived difficulty, lower levels of listening-related anxiety, and a strong perception of the usefulness of shadowing as a listening strategy. These quantitative trends were consistently supported by qualitative evidence from classroom observations and open-ended learner reflections, indicating increased engagement, listening awareness, and emotional comfort over time.

Importantly, the results suggest that shadowing contributes not only to cognitive aspects of listening but also to affective and behavioral dimensions of language learning. Learners described listening as becoming a more active, focused, and engaging process, contrasting with their earlier experiences of passive listening instruction. The gradual reduction in anxiety and the emergence of listening awareness behaviors highlight the value of repeated, scaffolded practice in helping learners adapt to challenging listening tasks.

From a pedagogical standpoint, the study underscores the potential of shadowing as a practical and adaptable technique for EFL classrooms. When implemented as a guided routine rather than an isolated drill, shadowing can support learner engagement and foster positive learning experiences, even within a relatively short instructional period. The findings suggest that teachers should prioritize appropriate pacing, consistent scaffolding, and learner reflection to maximize the benefits of shadowing-based listening instruction.

While the study is limited by its sample size and focus on perceptual data, it offers a meaningful contribution by foregrounding learners' voices and classroom experiences. Future research may extend this work by incorporating objective measures of listening performance, examining longer instructional periods, or exploring digital and autonomous applications of shadowing. Nonetheless, the present findings indicate that shadowing holds promise not only as a technique for developing listening skills but also as a means of enhancing learners' confidence, engagement, and overall experience of listening in EFL contexts.

References

1. Bove N, Stewart J (2009) The utility of shadowing. In: Stoke AM (ed.) JALT 2008 Conference Proceedings. Tokyo: JALT, 888–900.
2. Carey PW (1971) Verbal retention after shadowing and after listening. Perception and Psychophysics 9(1–B): 79–83.
3. Hsieh KT, Dong DH, and Wang LY (2013) A preliminary study of applying shadowing technique to English intonation instruction. Taiwan Journal of Linguistics 11(29): 43–66
4. Malekmohammad, F. , Salehi, H. , Tabatabaei, O. and Hashemi Shahraki, S. (2024). The Effect of Shadowing Technique on Elementary and Intermediate EFL Learners' Listening Comprehension. *Journal of Language Horizons*, *8*(4), 107-130. doi: 10.22051/lghor.2024.45427.1871
5. Minematsu, N. (2016). A Corpus-based Analysis of Shadowing Speech: Case of L2 English by Japanese Learners. https://doi.org/10.21437/ISAPH.2016-7
6. Shiki O, Mori Y, Kadota S, and Yoshida S (2010) Exploring differences between shadowing and repeating practices: an analysis of reproduction rate and types of reproduced words. Annual Review of English Language Education in Japan 21: 81–90.
7. Shiota, K. (2012). The effectiveness of shadowing on students' psychology in language learning. Journal of Accents Asia, 5(1), 71-83.

Philological sciences

BOOSTING EFL STUDENTS' ORAL COMMUNICATION THROUGH TED TALKS

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Abstract

Oral communication competence is a fundamental objective of English as a Foreign Language (EFL) instruction; however, many university students continue to experience difficulties in speaking fluently and confidently. These challenges are often linked to limited exposure to authentic language input and insufficient opportunities for meaningful oral interaction. This study investigates the effectiveness of integrating TED Talks into EFL instruction to improve the oral communication skills of second-year university students at Azerbaijan University of Languages in Baku. Using a quasi-experimental design, the study compares the speaking performance of an experimental group exposed to TED Talk–based instruction with that of a control group receiving traditional speaking instruction. Data were collected through pre- and post-speaking assessments and student feedback. Findings indicate that students who engaged with TED Talks demonstrated noticeable improvement in fluency, pronunciation, lexical variety, and speaking confidence. TED Talks constitute an effective pedagogical resource for enhancing oral communication skills in EFL classrooms.

Keywords: EFL, oral communication, TED Talks, authentic materials, speaking skills

The ability to communicate orally in English is a key indicator of language proficiency and an essential skill for academic, professional, and social interaction. In EFL contexts, university students are expected to express ideas clearly, participate in discussions, and deliver presentations in English. In our country, English has been taught as both an international and foreign language in schools and universities for many years. Sometimes, in order to accelerate and professionally master its fundamentals, it is organically included in the curriculum in Azerbaijan through additional, or more precisely, elective, classes. Despite this obvious fact, the teaching of this subject is, firstly, sometimes somewhat formal. Secondly, it is insufficiently qualified due to the lack of external psychological support in schools and universities. As a result, the following situation has arisen: our students of various ages and IQ levels experience significant difficulties with fluent foreign language speech. Furthermore, interference arises due to a combination of linguistic and psychological factors, for example, a growing sense of anxiety when completing assignments. This leads to a lack of self-confidence. Learning this language is also hampered by a limited vocabulary and common pronunciation errors. As for the professionalism of teachers, the teaching of English is hampered by a lack of consideration for reproductive experience. These are the components of insufficient interaction between teachers and students. Finally, it should be noted that purely traditional approaches to teaching, which, in the old-fashioned way, prioritize grammar and stylistic exercises without taking into account the natural communication situation and the introduction of innovative technological tools, are difficult and problematic to achieve success.

Oral communication encompasses fluency, coherence, pronunciation, and the ability to convey meaning effectively. Communicative language teaching emphasizes meaningful interaction and exposure to real-life language. Research in second language acquisition shows learners need models of natural speech and opportunities for purposeful output. In many EFL classrooms, limited and inauthentic speaking activities restrict communicative development.
Authentic materials are originally created for real communication rather than for language instruction. Studies show authentic materials enhance motivation, cultural awareness, and language competence. Video-based materials allow learners to observe both linguistic features and paralinguistic elements, such as facial expressions and gestures, which are critical for oral communication but often absent from textbooks.

TED Talks have become popular in EFL pedagogy due to their accessibility, engaging content, and educational value. Short, well-structured, and delivered by skilled speakers, TED Talks are suitable for classroom use. Subtitles and transcripts further support comprehension. Prior research reports that TED Talks improve listening, vocabulary acquisition, speaking performance, and confidence. However, studies in the Azerbaijani context are limited, and this study seeks to address this gap.

A quasi-experimental design compared the effects of TED Talk–based instruction with traditional speaking instruction.

Twenty-four second-year English-major students at Azerbaijan University of Languages participated, divided equally into an experimental and a control group. Both groups were intermediate-level learners taught by the same instructor, reflecting typical university class sizes and enabling close monitoring.

Data collection included:

- Speaking pre-test and post-test
- An oral communication rubric evaluating fluency, pronunciation, vocabulary, coherence, and confidence

Modern linguists and methodologists propose maximizing the integration of this process, infusing it with the latest multimedia technology and all kinds of authentic texts. Appropriate programs are now available that can help address this issue. One example is TED Talks. This program allows for the structuring and presentation of several topics. It is designed to provide students with a deeper understanding of the language, its accents, nuances, and advanced strategies. TED Talks has already proven itself to be an effective tool, particularly for developing oral speech, intonation, orthoepy, and more. TED Talks is also closely linked to English textual discourse and communication. Using such valuable tools, fluency in foreign language speech is undoubtedly improved, correct pronunciation is established, vocabulary is expanded, and psychological self-confidence is enhanced. These theoretical propositions have been confirmed by practical research. The experiment lasted approximately two months. Students in the control group developed and refined their oral communication skills using a textbook; students in the experimental group studied them in class by watching videos.

The TED Talks program was divided into three stages:

1. Watching a video followed by an assignment, which focused on discussing and analyzing English vocabulary.
2. Watching the videos directly with notes.
3. Post-viewing texts, summaries, conversations, discussion of opinions, critical reflection on the problem, and presentation.

Testing showed that students in the experimental group significantly outperformed the test in fluency and other areas noted above. Feedback confirmed the effectiveness of TED Talks, its informative nature, and its exploration of new stylistic norms and solutions. Methodologists and linguists now have access to a wealth of factual material on English language and communication. By integrating the program into the educational process, fluency can be significantly improved. The program is not particularly difficult for students to understand, making it quite accessible. It will undoubtedly help teachers establish a system of interactive lessons. We recommend conducting methodological and linguistic research in this area.

References

1. Ur P. *A course in English language teaching*. Cambridge University Press, 2012.

ARTISTIC REPRESENTATION OF MOSCOW IN 19TH-CENTURY RUSSIAN LITERATURE

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ХУДОЖЕСТВЕННОЕ ВОПЛОЩЕНИЕ ОБРАЗА МОСКВЫ В ПРОИЗВЕДЕНИЯХ РУССКОЙ ЛИТЕРАТУРЫ 19 ВЕКА

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Abstract

This article analyzes the image of Moscow in 19th-century Russian literature. By examining the urban text of Russian classical literature, the authors compare the images of the two capitals in the works of A.Pushkin, N.Gogol, A.Griboyedov, and other writers. The study concludes that in 19th-century literature, Moscow is often portrayed as a city of tradition and spiritual values, while St. Petersburg is associated with power and official order.

Аннотация

Данная статья посвящена анализу образа Москвы в русской литературе 19 века. Обращаясь к городскому тексту русской классической литературы, авторы сопоставляют образы двух столиц в произведениях А.С.Пушкина, Н.В.Гоголя, А.С.Грибоедова и других писателей. В результате исследования сделан вывод о том, что патриархальная Москва в литературе 19 века чаще представлена как город традиций и духовных ценностей, тогда как Петербург связан с образом власти и официального порядка.

Keywords: urban text, city image, Moscow, St. Petersburg, 19th-century Russian literature.

Ключевые слова: городской текст, образ города, Москва, Петербург, русская литература 19 века.

Образ города занимает важное место в русской литературе 19 века, выступая не только пространством действия, но и важным средством выражения авторской позиции. Москва в произведениях русских писателей осмысляется как значимый художественный образ, воплотивший представления о национальной истории, духовных ценностях и культурной традиции.

В рамках городского текста русской классической литературы образ Москвы нередко раскрывается в сопоставлении с образом Петербурга. В произведениях А.С.Пушкина, Н.В.Гоголя, А.С.Грибоедова и других авторов «патриархальная» Москва предстаёт как город традиций, «домашнего» и духовного начала, тогда как Петербург – город современный, европейский – связывается с образом государственной власти, официального порядка и рациональной организации жизни. Такое сопоставление позволяет глубже выявить художественную специфику образа Москвы в литературе 19 века.

Исследователь Л.Ф.Чертов обращается к изучению города в семиосфере культуры и подчёркивает, что город может быть связан с историей уже с самого момента своего возникновения, и

указывает на связь двух столиц – Москвы и Петербурга. Автор подчёркивает, что Петербург уже с самого момента своего основания осмысливался как антитеза древним центрам российской истории, в частности, как антитеза Москве. С другой стороны, Петербург является продолжателем целого ряда исторических прототипов – как уже «четвёртый Рим», появившийся после расцвета «второго Рима» (Константинополя) и «третьего Рима» (Москвы). «Эта умозрительная связь с имперским Римом, – подчёркивает исследователь, – была выражена с помощью семиотических средств «архитектурной латыни» в стиле ампир, который наглядно воспроизводил в пространственных формах внешние атрибуты имперской столицы» [1, 79].

На сегодняшний день тема города в русской классической литературе изучена уже достаточно подробно. Тем не менее, она по-прежнему привлекает внимание исследователей, так как анализ образа города помогает понять особенности личности автора и глубже проникнуть в художественный мир его произведений.

Обращаясь к анализу семиотики «городского текста» в русской литературе, Н.В.Бараханова подчёркивает, что уже с начала 19 века писатели разрабатывают городские образы и мотивы, и «формируется своеобразная концепция города, выкристаллизовываются «городские» мифы, в которых реальность причудливо сочетается с вымыслом и традицией». Город – это «способ организации, окультуривания и структурирования пространства, введение человеческого измерения в природный мир. Город преображает среду обитания посредством архитектуры» [2, с.7].

Т.Е.Трощинская-Степушина в статье «Город как символ: от пространства к имени» рассматривает город «не только и не столько как топографический объект, урбаноним, но как понятие, превращающееся в художественном пространстве автора в сложный символ-образ, сочетающий в себе, с одной стороны, жизнь многих, с другой – интимное существование одного» [3, с.449].

В своей монографии «Семиосфера» Ю.М.Лотман выделяет две основные сферы городской семиотики: город как пространство и город как имя [4, с. 325].

Русская классическая литература достаточно часто обращалась к созданию образа Москвы, рисуя город домашний и уютный, гостеприимный и хлебосольный. Необыкновенная теплота, которой проникнуты поэтические строки о Москве, связана с тем, что этот город был родным для многих поэтов и писателей, обратившихся к созданию его облика на страницах своих произведений. Москва – это родина А.С.Пушкина, М.Ю.Лермонтова, А.И.Герцена, Н.Гончарова и других авторов 19 века. Определённые традиции в изображении Москвы были заложены ещё Н.М.Карамзиным, который в романе «Бедная Лиза» рисует живописную панораму, окидывая её взглядом сверху, с вершины большого холма. Эту традицию впоследствии усвоит М.Ю.Лермонтов, который, вслед за Н.Карамзиным, использует подобный принцип панорамности в изображении города.

В одном из писем М.А.Лопухиной М.Ю.Лермонтов признаётся в любви к Москве, называя её своей единственной родиной («Там я родился, там много страдал и там же был слишком счастлив…»). Любовь поэта к Москве выразилась уже в одном из первых его произведений – «Панорама Москвы», где дано чисто романтическое восприятие и изображение города. Молодой поэт обращается к уже использованному ранее Н.Карамзиным принципу панорамности, изображая столицу сверху – с высоты 81-метровой колокольни Ивана Великого. В поле обзора М.Ю.Лермонтова попадают Кремль, Петропавловский замок, собор Василия Блаженного, Поклонная гора, Москва-река. Для очерка юного поэта характерно новое восприятие Москвы – как места пересечения Запада и Востока, Европы и России.

Важное место занимает образ Москвы в романе А.И.Герцена «Былое и думы». Писатель изображает столицу в тяжёлые героические дни сражений с Наполеоном – во время пожара Москвы 1812 года. Главное внимание писателя сосредоточено уже не на изображении московских пейзажей, радующих взор, а на передаче атмосферы московской жизни, стремлении уловить и запечатлеть дух Москвы. Особый акцент А.И.Герцен делает на культурной жизни столицы – прежде всего, это богатая театральная и литературная жизнь.

Москва в литературе 19 века – это город со спокойной размеренной жизнью, слегка замедленной и неторопливой, порой – немного застывшей. При чтении романа А.С.Пушкина «Евгений Онегин» создаётся невольное впечатление, что Москва – это город московских бабушек и тётушек: именно в этих традициях поэт рисует Москву в сцене приезда провинциальной барышни Татьяны в патриархальную полустоличную Москву, так контрастировавшую с деловой жизнью молодого Петербурга.

Обычно исследователи называют А.С.Пушкина по преимуществу петербургским писателем, хотя родился поэт в Москве и навсегда сохранил в сердце любовь к родному городу. В трагедии «Борис

Годунов» Москва в сознании поэта отождествляется с образом России в целом: «Там ждут тебя сердца твоих людей: // Твоя Москва, твой Кремль, твоя держава».

Образ Москвы мы встречаем в трагедии «Борис Годунов», повести «Гробовщик», очерке «Путешествие из Москвы в Петербург». Но самая широкая панорама столицы дана в 7 главе «Евгения Онегина».

К цитатной характеристике Москвы на страницах пушкинского романа в стихах обращается Дань Ши Дань в статье «Образ Москвы в романе А.С.Пушкина «Евгений Онегин». Анализируя образ Москвы, увиденный глазами Татьяны Лариной, автор статьи делает вывод о той роли, которую Москва сыграла в жизни главных героев романа А.С.Пушкина [5, с.291-293].

Интересно обратить внимание на следующую деталь в изображении портрета города. Деловая жизнь Петербурга противопоставляется немного провинциальной патриархальной Москве – и это проявилось на уровне грамматики. Рисуя Петербург в романе «Евгений Онегин», А.С.Пушкин использует большое количество глаголов. А для образа Москвы использует, в основном, имена существительные. Малое количество глаголов при преобладании имён существительных акцентирует неподвижность Москвы.

Обратим внимание на ряды существительных в описании московских улиц:

...Вот уж по Тверской
Возок несётся чрез ухабы.
Мелькают мимо *будки, бабы,*
Мальчишки, лавки, фонари,
Дворцы, сады, монастыри,
Бухарцы, сани, огороды,
Купцы, лачужки, мужики,
Бульвары, башни, казаки,
Аптеки, магазины моды,
Балконы, львы на воротах
И стаи галок на крестах.

В романе «Евгений Онегин» представлены образы двух столиц: Москва в изображении поэта – полустоличная, патриархальная, Петербург – современный европейский деловой город. По-разному изображаются московское и петербургское дворянство. Портрет московского дворянства дан несколько саркастично – вокруг один только «пошлый вздор» и ни одной живой мысли. Московское общество – это скука, сплетни и равнодушие. А.С.Пушкин говорит о «бесплодной сухости речей, расспросов, сплетен и вестей», в которых нет и искры живой мысли. «Всё в них бледно и равнодушно; // Они клевещут даже скучно». Акцентируемая поэтом скука роднит оба города. И для Онегина, и для Татьяны утомителен и скучен круг общения в обеих столицах, тягостны условности высшего общества; герои остаются не понятыми в этой среде, не находя «ни общих мнений, ни страстей».

Поэт называет Москву «порфироносною вдовой». Он видит, как утрачивается былое могущество Москвы, уступившей титул столицы новому городу – городу на Неве: «И перед младшею столицей померкла старая Москва...». Тем не менее, древняя Москва дорога поэту, и с особой нежностью и любовью А.С.Пушкин пишет:

Как часто в горестной разлуке,
В моей блуждающей судьбе,
Москва, я думал о тебе!
Москва... как много в этом звуке
Для сердца русского слилось!
Как много в нём отозвалось!

Особое место занимала Москва в жизни и судьбе Н.В.Гоголя. Побывав однажды в Москве, он полюбил этот город и не раз говорил, что жить хотел бы в Москве или Риме – только в одном из этих двух великих городов.

Н.В.Гоголь тоже противопоставляет размеренную жизнь патриархальной Москвы – города с длительной богатой историей и с купеческой важностью – шумному и многолюдному молодому Петербургу. Писатель сравнивает Москву с русским дворянином, который уж если веселится, то веселится до упаду. А Петербург рождает у писателя ассоциации с аккуратным на вид совершенным немцем, глядящим на всё с расчётом. Но писатель отдавал должное архитектуре столицы, называя её «щёголем Петербургом», а Невский проспект – «красавицей нашей столицы».

В комедии А.С.Грибоедова «Горе от ума» представлена иная линия восприятия Москвы, для которой характерно отсутствие какой бы то ни было поэтизации. У драматурга нет никакого

любования Москвой. Грибоедовская столица – это Москва Фамусова и иных представителей его общества – Молчалина, Скалозуба, Хлёстовой и других. Это город чиновников и родственных протекций, где благоденствуют те, кто может вовремя «подвинуть стул, подать платок», кто уважает чины и звания, кто успевает «и награжденья брать, и весело пожить».

В комедии «Горе от ума» характеристика Москвы звучит из уст Чацкого. Московская жизнь – это жизнь застывшая и однообразная, пустая и пошлая, бессодержательная и бездуховная. Весь смысл московского бытия сводится к званым обедам и званым погребеньям. Поэтому неудивительно, что идеалом московской жизни стал дядя Фамусова Максим Петрович. А.С.Грибоедов подчёркивает, что в Москве, в отличие от передового Петербурга, живут люди «века минувшего».

Хлебосольность Москвы изображали разные авторы 19 века. Но если Л.Н.Толстой в московских гостеприимстве и радушии видит необыкновенную поэзию, то для А.С.Грибоедова это – признак неразборочивости и лжегостеприимства (в гостиных Москвы бранят всякого – и принимают всякоко), неискренности и лицемерия. Поэт акцентирует увиденное им преобладание формы над содержанием (главное – чины и звания), косность мышления (книги – сжечь). Если в Петербурге на первый план выступают деловые качества человека, то в Москве всё зависит от родственных связей и знакомств («по отцу и сыну честь»).

Интересный облик столицы представлен в этнографически-бытовых очерках М.Н.Загоскина «Москва и Москвичи». Произведение имеет весьма характерное название. Автор упоминает здесь и город, и его жителей. Но Москва – это не только москвичи, а москвичи в понимании Загоскина – это не только Москва.

Москва изображена в очерках с разных позиций. Во-первых, как географический объект. Загоскин упоминает Пресненские пруды, Воробьёвы горы, Новодевичий монастырь, Марьину рощу, Москву-реку, речку Яузу и многие другие места. Во-вторых, как «родной» город самого писателя. В-третьих, Москва представлена как столица России. Особое внимание М.Загоскин уделяет вопросу о соперничестве Москвы и Петербурга. В-четвёртых, в мельчайших подробностях показана эпоха начала 19 века (описание быта, одежды, увлечений, образования, архитектуры и мн. др.).

О.Шурупова отмечает, что «Первопрестольная столица проявляет в посвящённых ей текстах различные, иногда взаимоисключающие друг друга черты». Также автор обращает внимание на то, что во всех произведениях, вошедших в московский текст, действие происходит именно в Москве. В романах «Евгений Онегин» А.С.Пушкина и «Война и мир» Л.Н.Толстого изображается не только Москва, но также и Петербург, и провинция. Тем не менее, по мысли исследователя, они «содержат значимые именно для Московского текста русской литературы концепты, с помощью которых в пределах этих произведений создается особая сверхтекстовая картина московской жизни» [6, с.1243].

Итак, русская литература 19 века создаёт многоликий образ Москвы, закладывая традиции как сатирического изображения города, так и объективной, порой поэтизированной его обрисовки. Писатели 20 века во многом продолжат намеченную тенденцию.

Подводя итоги, ещё раз подчеркнём, что анализ образа Москвы в русской литературе 19 века показывает, что данный образ формируется как носитель национальных и духовных ценностей. В сопоставлении с Петербургом Москва приобретает значение внутреннего культурного пространства, связанного с исторической памятью и традицией. Это позволяет рассматривать образ Москвы как важный элемент авторской картины мира русских писателей 19 века.

References

1. Chertov, L.F. The City in the Semiosphere of Culture: The Semiotized Space of Saint Petersburg // Man: Image and Essence. – 2022. – No. 1. – Pp. 62-87. – https://www.elibrary.ru/item.asp?id=47984739
2. Barakhanova N.V. On the Semiotics of the "Urban Text" in Russian Literature // Kazan Science. – 2021. - No. 6. – Pp. 7-9.– https://www.elibrary.ru/query_results.asp
3. Troshchinskaya-Stepushina T.E. The City as a Symbol: From Space to Name // Scientific Notes of the Crimean Federal University named after V.I. Vernadsky. – Philological Sciences. – 2012. – Vol.25 (64). – No.1. – Pp.446-450.
4. Lotman Yu.M. Semiosphere. – St. Petersburg: Iskusstvo – SPB, 2000. – 704 p.
5. Dan Shi Dan. The Image of Moscow in Alexander Pushkin's Novel "Eugene Onegin" // Innovative Support for Level-Based Education for Students in Higher Education Institutions. – 201. – Pp. 291-293.– https://elibrary.ru/item.asp?id=29091652
6. Shurupova O.S. The Natural Sphere of the Moscow Text of Russian Literature// Fundamental Research. – 2014. – No. 8-5. – Pp. 1243-1246. –https://www.elibrary.ru/item.asp?id=21773210

Philosophical sciences

ESSENCE AND TYPES OF THINKING: CONCEPTUAL CHARACTERISTICS

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СУЩНОСТЬ И ТИПЫ МЫШЛЕНИЯ: КОНЦЕПТУАЛЬНАЯ ХАРАКТЕРИСТИКА

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Abstract

In this article, the authors analyze the essence and main types of thinking. Particular attention is paid to speculative thinking. It is noted that the concept of speculative thinking is sometimes perceived critically, and that it is a vague and abstract term that can be misleading. This is most likely due to the metaphysical understanding of the essence of speculative thinking. The conceptual content of empirical thinking is examined. It is emphasized that it has its limitations and is an important tool in science and many practical areas, allowing for rational and well-founded conclusions based on facts and experience. In addition, other types of thinking (abstract, dialectical, logical, etc.) and their differences are considered. It is noted that thinking is a broader concept that describes the process of information processing in the human mind. It includes perception, analysis, synthesis, abstraction, generalization, and conclusions based on the information received. Thinking can be logical, analytical, critical, creative, and others.

Аннотация

В данной статье авторами проводится анализ сущность и основные типы мышления. Особое внимание уделено спекулятивному мышлению. Отмечено, что понятие спекулятивного мышления иной раз воспринимается критически, и что оно суть неопределенный и абстрактный термин, который может вводить в заблуждение. Это скорее всего происходит из-за метафизического понимания сущности спекулятивного мышления. Рассмотрены концептуальное содержание эмпирического мышления. Подчеркивается, что оно имеет свои ограничение и является важным инструментом в науке и многих практических областях, позволяя сделать рациональное и обоснованные выводы на основе фактов и опыта. Кроме того, рассмотрены и другие типы мышления (абстрактное, диалектическое, логическое и др.) и их отличие. Отмечено, что мышление — это более широкое понятие, которое описывает процесс обработки информации в человеческом разуме. Он включает в себя восприятие, анализ, синтез, абстрагирование, обобщение и выводы на основе полученной информации. Мышление может быть логическим, аналитическим, критическим, творческим и другими.

Keywords: thinking, thought, speculative thinking, empirical thinking, abstract thinking, analytical thinking, logical and creative thinking, critical thinking.

Ключевые слова: мышления, мысль, спекулятивное мышление, эмпирическое мышление, абстрактное мышление, аналитическое мышление, логическое и творческое мышление, критическое мышление.

Мышление — это исследование, когда реальная система разбивается на отдельные компоненты, где выделяются ключевые точки и ориентация в дальнейшем идет по этим точкам. Мыслительный процесс сводит реальное положение вещей к идеальному, разбивая весь процесс на части, — по отношению к каждой из частей строится модель, а дальше идет изучение моделей и их взаимоотношений. Последующее изменение реальной вещи возможно лишь потому, что было произведено изменение ее идеальной модели [1]

Спекулятивное мышление в контексте практического сознания — это мышление, основанное на предположениях, домыслах, гипотезах и предположительных выводах, которые не обоснованы достаточным количеством доказательств или данных. Потому, спекулятивное мышление может быть полезным инструментом в исследованиях и научных исследованиях, но только если оно используется с осторожностью и сопровождается достаточным количеством эмпирических данных и проверкой гипотез. В экономике, спекулятивное мышление может привести к необоснованным финансовым решениям и рискованным инвестициям.

Георг Вильгельм Фридрих Гегель (1770-1831) определял спекулятивное мышление как процесс, в рамках которого мы устраняем различия между противоположностями и синтезируем их в более высокую форму единства. Гегель считал, что спекулятивное мышление — это более высокий уровень мышления, чем абстрактное или эмпирическое мышление.[2] По его мнению, спекулятивное мышление применяется в философии, искусстве и науке, а также в повседневной жизни, чтобы преодолеть диалектические противоречия и добиться высшего единства. Он считал, что это происходит через процесс тезиса, антитезиса и синтеза, когда мы начинаем с противоположных понятий, разрешаем их противоречия и объединяем их в более высокую форму единства. В то же время, он предостерегал от чрезмерного увлечения спекулятивным мышлением, которое может привести к абсолютизации наших идей и концепций, и, следовательно, к закрытию нашего ума для новых идей и опыта.

По мнению Гегеля спекулятивное мышление в отличие от "аналитического" или "абстрактного» не только анализирует и разбирает на составные части, но и восстанавливает целостность и связь между этими частями. Стало быть, спекулятивное мышление представляет собой "диалектический" процесс, который включает в себя три стадии: тезис, антитезис и синтез. Тезис — это начальное положение или утверждение, а антитезис — это противоположное утверждение или отрицание тезиса. Синтез объединяет эти два противоположных полюса в более высокую, объединенную и прогрессивную форму мышления. Оно имеет принципиальное значение для понимания сложных и противоречивых явлений, которые не могут быть объяснены с помощью аналитического мышления. Он также утверждал, что спекулятивное мышление позволяет нам перестроить и улучшить наши представления о мире, выйти за рамки повседневных представлений и привычек, и достичь более глубокого понимания реальности. Следует отметить, что понятие спекулятивного мышления иной раз воспринимается критически, и что оно суть неопределенный и абстрактный термин, который может вводить в заблуждение. Это, по нашему мнению, скорее всего происходит из-за метафизического понимания сущности спекулятивного мышления.

Далее нам целесообразно выяснить суть и концептуальное содержание эмпирического мышления. Эмпирическое мышление — это тип мышления, основанный на наблюдении и опыте, которое использует сенсорные данные и эмпирические факты, чтобы делать выводы и принимать решения. Оно широко применяется в науке и практических областях, таких как медицина, психология, экономика и инженерия. Как тип мышление оно предполагает, что знания возникают из опыта и наблюдения, и что знание основано на фактах и эмпирических данных. Подобный концепт противоположно спекулятивному мышлению, которое может быть основано на предположениях, домыслах и гипотезах, не подтвержденных наблюдением или опытом. В области науки оно является ключевым фактором в методе научного исследования и предполагает сбор данных, проведение экспериментов и анализ результатов, чтобы проверить гипотезы и теории. В практических областях, таких как медицина, психология или инженерия, эмпирическое мышление помогает принимать решения на основе фактов, а не только на основе интуиции или предположений. Однако, данное мышление имеет свои ограничения, оно является важным инструментом в науке и многих практических областях, позволяя сделать рациональные и обоснованные выводы на основе фактов и опыта.

Абстрактный тип мышление в отличие эмпирического, использует абстрактные концепции и идеи для анализа, понимания и решения проблем. Оно также использует логические операции, такие как классификация, сравнение и анализ, чтобы извлечь смысл из информации и создать общие правила и принципы. Как тип мышления оно преимущественно используется в науке, математике, философии и лингвистике, а также в практических областях, таких как бизнес и управление. Ибо, оно позволяет анализировать сложные проблемы, определять главные факторы и создавать абстрактные модели, которые могут помочь в принятии решений. В этой связи, С.Л. Рубинштейн подчеркивал, что «всякий мыслительный процесс является по своему внутреннему строению действием или актом деятельности, направленным на разрешение определенной задачи. Задача эта заключает в себе цель для мыслительной деятельности индивида, соотнесенную с условиями, которыми она задана» [3]

Абстрактное мышление часто противопоставляют конкретному мышлению, которое ориентировано на реальный мир и сенсорный опыт. Абстрактное мышление в противовес этому позволяет рассматривать идеи и концепции отвлеченно, без привязки к конкретным объектам или ситуациям. В справедливости ради следует отметить, что оно может быть полезным в анализе и решении проблем, но также может быть ограничено и не всегда применимо к конкретным ситуациям. К примеру, в медицине, где важна точность диагноза и лечения, абстрактные модели и концепции могут быть недостаточными для определения диагноз конкретной болезни и ее методику лечения.

Основное отличие между эмпирическим и абстрактным мышлением заключается в том, что эмпирическое мышление ориентировано на сенсорный опыт и конкретные данные, тогда как абстрактное мышление использует абстрактные концепции и идеи. Эмпирическое мышление базируется на наблюдении и опыте, и использует факты и данные, чтобы принимать решения и делать выводы. Оно применяется в науке, медицине, психологии и других практических областях, где важно рассматривать реальный мир и основываться на сенсорных данных. Кроме того, эмпирическое мышление часто связано с использованием научного метода и экспериментального подхода, тогда как абстрактное мышление использует логические операции и анализ, чтобы извлечь смысл из информации.

Абстрактное мышление, напротив, использует абстрактные концепции и идеи для анализа, понимания и решения проблем. Оно применяется в математике, философии, лингвистике и других теоретических областях, где важно рассматривать идеи и концепции отвлеченно и без привязки к конкретным объектам или ситуациям. Оба типа мышления с точки зрения науки важны и могут быть полезными в различных областях знания и практики. Часто для решения сложных проблем и принятия обоснованных решений необходимо использовать как эмпирическое, так и абстрактное мышление в сочетании, чтобы получить более полное понимание проблемы и найти эффективное решение.

Что есть диалектическое мышление, это тип мышления, который был развит в работах Гегеля и Маркса, и который включает в себя процесс постоянного развития и изменения. Согласно данному типу мышления мир и мысли, связанные с ним, находятся в постоянном движении и развитии, и это движение происходит через взаимодействие различных противоречивых сил, иными словами, внутренние противоречия того или иного явления создают напряжение, которое затем приводит к его развитию и изменению. Диалектическое мышление включает в себя три стадии: тезис - начальное утверждение или позиция; антитезис - противоположное утверждение или позиция; синтез - новое утверждение или позиция, которая является результатом взаимодействия тезиса и антитезиса.

Классическим примером триады тезис-антитезис-синтез является философский подход Гегеля к истории, тезис - идея, что история развивается в соответствии с планом Абсолюта, и что люди не имеют контроля над этим процессом; антитезис – идея что история не является заранее заданной, а скорее является результатом действий и выборов людей; синтез – идея что история является процессом взаимодействия между Божественной волей и действиями людей, и что развитие истории происходит через этот процесс взаимодействия. Изложенная триада показывает, как Гегель использует диалектическое мышление для объяснения сложных и противоречивых явлений, таких как история. Применение диалектического подхода в процессе теоретического мышления позволяет более глубоко понимать, как различные противоречия могут быть разрешены посредством постоянного движения и развития.

В отличие от Гегеля, его предшественник Иммануил Кант в своей философской системе не прибегал к понятию "спекулятивное мышление", он выдвинул идею о том, что наше знание о мире ограничено человеческим опытом и разумом. И разработал концепцию "априорных категорий" являющиеся необходимыми условиями познания «вещей для нас». Иными словами, по данной концепции, под воздействием непознаваемого «вещи в себе» в сознании возникают феномены (явлении) и только эти феномены доступны для человеческого познания как такового. Кант также

предложил различие между "аналитическими" и "синтетическими" суждениями, где аналитические суждения являются просто разъяснением уже содержащихся в определении понятий, а синтетические суждения добавляют к определению новую информацию, которая не является очевидной из самого определения. Кант, по существу, отвергал спекулятивное мышление, которое основывается на предположениях или гипотезах, которые нельзя подтвердить опытом. Он считал, что знание должно быть основано на четких определениях и априорных категориях, а не на спекуляциях.

Рассуждая о таких, сложных типов мышления как спекулятивное и диалектическое нам следует хотя бы вскользь заметить о понятии «мысль». Мысль — это понятие, которое используется для описания процесса или продукта мышления, то есть процесса обработки информации и получения знаний в человеческом разуме. Мысль может быть определена как форма активности разума, включающая в себя восприятие, анализ, синтез, абстрагирование, обобщение и выводы на основе полученной информации. Мысль может быть как процессом, когда размышляющий человек использует свой разум, чтобы рассуждать о чем-то, или продуктом этого процесса, который может быть выражен в виде слов, письменных высказываний или других форм коммуникации. Мысль является ключевой составляющей человеческой интеллектуальной деятельности и формирования знаний, понимания и мнений о мире вокруг нас.

Каково концептуальное соотношение понятий «мысль» «мышление». Мысль и мышление — это два тесно связанных понятия, которые используются для описания процессов, происходящих в человеческом разуме. Мышление — это более широкое понятие, которое описывает процесс обработки информации в человеческом разуме. Он включает в себя восприятие, анализ, синтез, абстрагирование, обобщение и выводы на основе полученной информации. Мышление может быть логическим, аналитическим, критическим, творческим и другими. [4] Мысль — это продукт или результат мышления. Мысль может быть выражена в виде слов, письменных высказываний или других форм коммуникации. Она может быть как конкретной, так и абстрактной, и описывает способность человеческого разума генерировать идеи, создавать связи между понятиями и формулировать выводы на основе информации. Мышление и мысль тесно связаны друг с другом: мышление порождает мысли, а мысли, в свою очередь, влияют на процесс мышления, обогащая его новыми идеями и концепциями.

В целом логическое мышление - это способность человеческого разума к абстрагированию и установлению логических связей между понятиями и идеями. Оно основано на принципе закономерности и стремится к достижению правильных и логически обоснованных выводов на основе имеющихся фактов и данных. Логическое мышление включает в себя различные типы логических операций, таких как анализ, синтез, классификация, абстрагирование, обобщение, дедукция, индукция и другие. Оно также включает в себя различные типы логических структур - категории, суждения и умозаключения, которые имеют существенное значение в решении проблем, принятии решений и формировании аргументов в дискуссиях и обсуждениях. Оно способствует развитию аналитических и критических способностей, повышению эффективности мышления и улучшению качества жизни в целом. Начало пониманию определения мышления заложил нидерландский философ-рационалист Бенедикт Спиноза в своем сочинении «Этика» [5].

Аналитическое мышление — это способность человеческого разума к анализу, декомпозиции и изучению сложных проблем и задач, с целью выделения ключевых элементов и понимания их взаимосвязей. Это способность рассматривать проблему или ситуацию в целом, а затем разбивать ее на более мелкие составляющие, которые легче изучать и понимать. Аналитическое мышление предполагает использование логических инструментов и методов для анализа и оценки информации, а также развитие критического и логического мышления. Оно включает в себя способность к классификации, дифференциации, сравнению и оценке данных и фактов, что позволяет принимать обоснованные решения и достигать поставленных целей. Аналитическое мышление имеет широкое применение в различных областях жизни, включая науку, бизнес, технологии, образование, политику и другие. Это способствует развитию новых идей и концепций, а также повышению эффективности в решении проблем и достижении поставленных целей.

Критическое мышление — это способность человеческого разума к анализу и оценке информации и идей, с целью формирования обоснованных выводов и принятия осознанных решений. Оно предполагает осознанный и аналитический подход к рассмотрению информации, особенно той, которая может быть введена в заблуждение или ошибочна. Критическое мышление включает в себя не только оценку информации, но и обоснованное принятие решений на основе анализа данных. Это означает, что человек, использующий критическое мышление, способен оценить все возможные альтернативы, рассмотреть их плюсы и минусы, и только после этого принять решение, которое будет оптимальным для данной ситуации. Критическое мышление включает в себя такие навыки, как оценка

доказательств, анализ причинно-следственных связей, выявление логических ошибок и противоречий, оно позволяет принимать обоснованные решения, опираться на факты и анализ, а также адекватно осмсылить окружающий мир.

Творческое мышление — это способность генерировать новые идеи, концепции и решения проблем, которые являются оригинальными, инновационными и уникальными. Оно связано с творческим процессом, который может быть проявлен в различных сферах жизни, таких как наука, искусство, музыка, литература, дизайн и другие. Творческое мышление требует свободного и независимого мышления, открытости новым идеям, готовности рисковать и искать нестандартные решения. Это может включать в себя использование ассоциативного мышления, где идеи, связанные между собой по аналогии или сходству, могут привести к новым оригинальным концепциям. Оно требует развития таких навыков, как умение задавать вопросы, поиска новых решений, а также готовности к экспериментам и изменениям.

Завершим нашу статью словами Гегеля “если логика, как утверждают, лишена содержания, то это вина не предмета логики, а только способа его понимания”.

References

1. Davidov [Definition of Thinking // Cultural-Historical Psychology
-2006. Vol. 2. No. 2. – pp. 3-6. Internet resource:
https://psyjournals.ru/journals/chp/archive/2006_n2/

2. Bykova M.F. Hegel's Understanding of Thinking / Ed. Motroshilova N.V. - Moscow: Nauka, 1990. - 126 p.

3. Rubinstein S.L. Fundamentals of General Psychology / S.L. Rubinstein. - 3rd ed. - St. Petersburg: Piter, 1999. - 317 p.

4. Zotov A.F. The Structure of Scientific Thinking. - Moscow: Politizdat, 1973. – 182 p.

5 Spinoza B. Ethics / Trans. from lat. N. A. Ivantsova. - St. Petersburg: Asta-press ltd, 1993. - 248 p.

Physical sciences

FORMULAS SPEAK: A CREATİVE APPROACH TO THE INTEGRATED TEACHİNG OF MATHEMATİCS AND PHYSİCS

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Abstract

This article examines the teaching of physics and mathematics in secondary schools, along with their foundations, by referencing the scientific works of eminent physics and mathematics scholars regarding the integration of these sciences.

Keywords: physics, mathematics, interdisciplinary connection, dependence, formula, modeling

Introduction

In the deep layers of the history of science, the two most powerful domains of knowledge—mathematics and physics—formed from humanity's desire to comprehend nature and have never existed in isolation from one another. Each in its own way strives to understand the regularities of the universe, but when these two fields merge, human thought begins to speak, as it were, in the "language of formulas." Formulas are not merely collections of symbols; they are nature's "speech," the music of energy, motion, mass, and time. Therefore, the integration of mathematics and physics in the modern educational process is not simply an interdisciplinary connection, but the cultivation of scientific thinking (Əliyev, 2018).

The most important idea underlying science is that nature is governed by mathematical laws. This idea was first systematically advanced by Galileo Galilei. He wrote: "The book of nature is written in the language of mathematics." (Galilei, 1638).

For Galileo, mathematics was the key to unlocking nature's symbolic cipher. He always sought mathematical relationships behind the physical phenomena he observed. For example, his observations on the law of free fall led to the establishment of the following relationship:

$$s = \frac{1}{2}gt^2$$

This formula was a revolution for both mathematics and physics: here, distance s is proportional to the square of time. Mathematics described this connection formally, while physics demonstrated its empirical truth. In this regard, the historical development of mathematics and physics is essentially a history of joint progress. Mathematics provides the form, physics provides the content; one is the "word," the other is the "meaning."

Ancient Greek thinkers—Pythagoras, Archimedes, Euclid—formulated the first theoretical ideas based on the connection between mathematics and physics. Pythagoras's idea that "everything is number" laid the philosophical foundation for the mathematization of physics (Aristotle, Metaphysics). Archimedes brought this idea to a practical level: his law of buoyancy

$$F_A = \rho g V_c$$

is one of the world's first mathematical physics formulas. Here, a quantitative relationship is shown between density (ρ), gravity (g) and the volume of the body (V_c) This demonstrated that mathematics was not merely a tool for measurement but also a means of expressing laws.

Euclid's work "Elements of Geometry" became the foundation for the future theoretical mathematical apparatus of physics. The concepts of geometry—point, line, plane—later transformed into the mathematical tools necessary for describing motion in Newtonian mechanics (İsmayılov, 2016).

The English scientist Isaac Newton (1643–1727) elevated the synthesis of these two sciences to the highest level. His work "Mathematical Principles of Natural Philosophy" (1687) is considered the beginning of a scientific revolution. In this work, Newton expressed the law of universal gravitation as follows:

$$F = G\frac{m_1 m_2}{r^2}$$

Here, mathematics and physics are inseparably united. The quantitative expression of the gravitational force is formulated as a mathematical model, but its physical meaning explains the interaction of forces on a cosmic scale.

Although Newton's formulas were written in the language of mathematics, at their depth lay the philosophy of physics: the interdependence of motion, time, and space. Precisely this synthesis later led to the emergence of the scientific direction known as mathematical physics (Ландау, 1988).

In the 19th century, James Maxwell systematized the laws of electromagnetism and presented them in the form of four mathematical equations. These equations are a miraculous union of both physics and mathematics:

$$\nabla \cdot E = \frac{\rho}{\varepsilon_0}, \nabla \cdot B = 0, \nabla \times E = -\frac{\partial B}{\partial t}, \nabla \times B = \mu_0 J + \mu_0 \varepsilon_0 \frac{\partial E}{\partial t}$$

In these equations, the symbols of differential and vector analysis describe physical realities—the behavior of electric and magnetic fields—in a mathematical language that "speaks." Maxwell's ideas also showed that mathematics is not just a calculation tool, but a means of thinking. After this stage, physics began to create new branches of mathematics to describe phenomena: differential equations, vector analysis, group theory, etc.

In the 20th century, this connection grew even stronger. Einstein's theory of relativity transformed a branch of mathematics (Riemannian geometry) into the foundation of physics:

$$E = mc^2$$

and

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

These equations represent the most mathematical form of physics. Here, each symbol— $R_{\mu\nu}, g_{\mu\nu}, T_{\mu\nu}$— carries both mathematical and physical significance. Thus, nature's "mathematical language" not only explains natural phenomena but also allows for the prediction of new laws (Розенблюм, 2019).

In Azerbaijani scientific schools, this connection has always been a focus of attention. Scholars such as Academician Həsən Abdullayev and Zahid Xəlilov have conducted significant research in both theoretical physics and mathematical analysis. For example, Prof. Zahid Xəlilov's work "Equations of Mathematical Physics" (Baku, 1963) is considered one of the fundamental textbooks in this field in the post-Soviet space. He provides not only the mathematical but also the physical interpretation of the equations.

Simultaneously, the idea of integrated teaching of mathematics and physics in Azerbaijani schools began to be implemented in the 1980s (Əliyev, 1989). Within the framework of the concept of "polytechnic education" at that time, students were encouraged to relate mathematical models to physical phenomena.

For instance, experiments conducted in Baku schools in 1985 on the topic "Mechanics and Functions" showed that integrated teaching resulted in a 22% increase in the average achievement level of students (Əhmədov, 1986). This proves that the mutual teaching of mathematics and physics yields real results.

In modern science, the concept of mathematical modeling holds a central place. When a physical phenomenon cannot be observed directly, its mathematical model is constructed. For example, the Fourier equation is written for the heat conduction process:

$$\frac{\partial T}{\partial t} = \alpha \nabla^2 T$$

Here, T– is temperature, t –is time, and α –is the thermal diffusivity coefficient. This equation is tested both mathematically and physically and corresponds with experimental results.

Such models can also be applied in school teaching. For example, while studying the topic "Heat Transfer" in the 10th grade, students can describe the change in temperature over time using functions and graphs. This approach develops both mathematical analytical thinking and physical intuition.

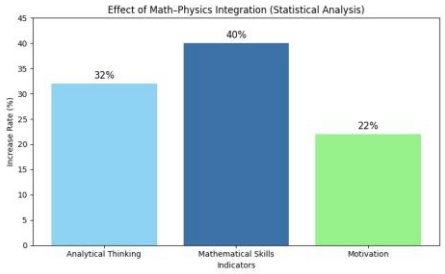
Research conducted in teaching practice shows that when mathematics and physics are taught in an interconnected manner:

- Students' analytical thinking ability increases by 28–35%;
- The skill of using mathematical symbolic language in problem-solving rises by up to 40%;

• The level of motivation increases by more than 20% (Rzayev, 2023).

This data proves that the integrated teaching of mathematics and physics is not merely an interdisciplinary connection but also a method for cultivating scientific thought.

Mathematical modeling is the process of expressing phenomena occurring in nature through mathematical symbols. This method was formed as a fundamental research method in physics in the 17th century and became a primary direction in teaching methodology in the 20th century (Ландау, 1988; Əliyev, 2018).



The upward lines in the chart represent the increase in achievement, thinking, and motivation indicators.

Every physical phenomenon is characterized by certain quantities and their interrelationships. Mathematics presents this relationship in the form of functions, equations, and graphs. For example, the formula describing the rectilinear uniform motion of objects:

$$s = vt$$

where distance sacts as a direct proportional function of velocity v, and time t.

This formula is a concrete physical manifestation of the linear function ($y = kx$) in mathematics. Thus, the student sees the concept of "linear function" not only in a graph but also in real motion. This serves to concretize mathematical abstraction in the teaching process (Quliyev, 2020).

Constructing a mathematical model consists of four main stages:

1. Determining the physical essence of the problem.
2. Selecting the main parameters of the phenomenon.
3. Establishing a mathematical relationship between these parameters.
4. Testing the model and interpreting the results (Rzayev, 2023).

Graphs are the most effective tool for the visual presentation of abstract concepts in teaching. They develop both the student's logical and aesthetic thinking.

The concept of "creative laboratories" is widely applied in modern lessons. In these laboratories, students conduct real experiments and graph the results in programs like Excel, GeoGebra, or Python. This elevates both mathematical and physical thinking to a digital level (Əliyev, 2021). For example, students conduct an experiment on "free fall," collect distance and time data, and then graph them on a computer. The resulting graph is parabolic, perfectly matching the function studied in mathematics lessons. This method implements the principle of "learning by discovery" and elevates the "formulas speak" approach to a practical level (Quliyev, 2020; Rzayev, 2023).

Mathematics and physics are not only scientific logic but also carry aesthetic values. Many scientists note that simple and beautiful formulas reflect the deep harmony of nature (Dirac, 1952). For example, the beauty of Maxwell's equations or the expression $E = mc^2$ lies in their universality.

In this regard, a creative teaching approach presents mathematical thinking to students not only as calculation but also as a form of beauty (İsmayılov, 2016).

Pilot projects conducted in some Azerbaijani lyceums and gymnasiums from 2020 to 2024 show that the application of mathematical modeling methodology has significantly improved student outcomes. The following table reflects this (Rzayev, 2023):

School Type	Number of Integrated Lessons	Achievement Increase	Student Satisfaction
Technical Lyceum	12	+28%	87%
Academic Gymnasium	15	+32%	91%
Pilot Secondary School	8	+25%	82%

These results indicate that the mathematical model simplifies the learning of the subject because it shows the rationality and regularity of the phenomenon (Səlimova, 2022; Əliyev, 2021).

Thus, mathematical modeling makes the language of physics more comprehensible and directly connects mathematics with nature. When formulas begin to "speak," the student understands not only the result but also its origin. This approach develops scientific logic, creative thinking, and aesthetic perception. Therefore, mathematical models are not only an analytical tool in teaching but also a means of thought and creativity (İsmayılov, 2016; Dirac, 1952; Rzayev, 2023).

Modern educational philosophy shows that when knowledge is fragmented, its meaning weakens, but when connections are established between sciences, the learning process becomes more meaningful and lasting. This integration between mathematics and physics is a natural necessity because both sciences explain the same natural phenomena from different perspectives. In this sense, integrative teaching means that subjects complement each other in content and methodology, creating synergy on common topics (Əliyev, 2019).

Such an integrative approach fosters in students not only theoretical knowledge but also mathematical thinking habits, analytical analysis, and creative problem-solving abilities.

In the traditional teaching model, mathematics and physics are taught as separate subjects. The student learns the "derivative" as a calculation tool in mathematics class but often fails to grasp its connection with the concepts of velocity and acceleration.

Teaching Model	Content Connection	Student Activity	Outcome
Traditional	Subjects are separate	Information is memorized	Short-term memory
Integrative	Mathematical concepts are combined with physical phenomena	Active research, problem-solving	Deep and lasting knowledge

Pilot projects conducted in Azerbaijani schools in 2022–2023 (Rzayeva, 2023) have shown that in the integrative lesson model, students' overall success rate increased by 18–25%. This confirms that teaching is not merely the transfer of information but also a process of developing scientific thinking skills.

Mathematics and physics are the two wings of the human intellect—one teaches abstract thinking, the other teaches understanding the real essence of natural phenomena. Their integration is not only an interdisciplinary union but also a process of integrating science, thought, and personality. The scientific and psychological analyses conducted in this article have shown that when mathematical and physical knowledge are presented together, the teaching process deepens cognitively and comes alive emotionally and creatively.

The most important result of integrative learning is the transformation of the student from a passive knowledge receiver into an active knowledge creator. When the logical consistency of mathematics combines with the experience-based realism of physics, education becomes a chain of "theory–practice–creativity." Each link of this chain forms new synaptic connections in human thinking, as a result of which cognition becomes flexible, systematic, and creative.

Comparative studies show that during the integrative teaching of mathematics and physics:

- Students' scientific interest and motivation increase 1.5–2 times.
- The speed of analytical problem-solving rises.
- The ability to relate abstract concepts to concrete situations is strengthened.
- A balance is created between scientific thinking and aesthetic perception (Əliyev, 2021; Hüseynova, 2019).

These results prove that mathematical-physical integration is not merely a methodological innovation—it is a change in teaching philosophy. If classical teaching transferred knowledge, integrative teaching creates knowledge; if the previous model taught the student, the new model teaches them to think.

Moreover, such a form of teaching reveals the creative potential of both the teacher and the student. The teacher is no longer an "information carrier" but a constructor of a scientific thinking environment. The student is no longer a "task performer" but a researcher of the problem. This mutual creative process also creates conditions for the formation of 21st-century skills (4Cs: creativity, critical thinking, communication, and collaboration), which are the main goal of modern education.

Summarizing all this, it can be said that when "formulas speak"—that is, when mathematics and physics enter into a scientific dialogue—the educational process transcends mere knowledge transfer and transforms into the intellectual and moral evolution of the individual. As a result of this integration, the individual who emerges sees the world not only through formulas but also through the prism of thought and creativity.

Thus, a creative approach to the integrated teaching of mathematics and physics forms the foundation for the future scientific and cultural development. This is the essence of 21st-century educational philosophy: mathematics thinks, physics speaks, and humanity creates.

References

1. Əliyev, S. (2021). Cognitive Motivation and Emotional Participation in Integrative Learning. *Azerbaijan Education Journal*, No. 3, pp. 45–52.
2. Hüseynova, Z. (2019). *Scientific-Cognitive Development of Personality and Integration of the Teaching Process*. Baku: Təhsil Nəşriyyatı.
3. Yusifov, A. (2020). *Development of Creative Thinking in the Teaching of Mathematics*. Baku: Elm və Təhsil.
4. Əhmədov, M. (1986). *Teaching Integration on Mechanics and Functions*. Baku: Təhsil.
5. Əliyev, S. (1989). *Theoretical Foundations of Polytechnic Education*. Baku: Maarif.
6. Əliyev, S. (2018). *Mathematical Model and Scientific Thinking*. Baku: Elm.
7. Əliyev, S. (2019). Integrative Teaching and Philosophy of Cognition. *Azerbaijan Education Journal*, No. 2.
8. Dirac, P. A. M. (1952). *The Principles of Quantum Mechanics*. Oxford University Press.
9. Galilei, G. (1638). *Discorsi e Dimostrazioni Matematiche intorno a due nuove scienze.* Leiden.

10. İsmayılov, A. (2016). *The Philosophical Foundation of Mathematics and Physics*. Baku: Elm.
11. Landau, L. D., & Lifshitz, E. M. (1988). *Theoretical Physics.* Moscow: Nauka.
12. Quliyev, R. (2020). *Mathematical Modeling and Physics Teaching*. Baku: Təhsil Nəşriyyatı.
13. Rosenblum, B. (2019). *Quantum Enigma: Physics Encounters Consciousness.* Oxford University Press.
14. Rzayev, E. (2023). Statistical Analysis of Integrative Teaching. *Science and Education*, No. 1.

COMPUTER SIMULATION OF THE RESULTS OF THE OPTICAL AND RHEOLOGICAL PROPERTIES OF 1,4-BENZODIOXANE

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КОМПЬЮТЕРНОЕ МОДЕЛИРОВАНИЯ РЕЗУЛЬТАТОВ ИССЛЕДОВАНИЯ ОПТИКО-РЕОЛОГИЧЕСКИХ СВОЙСТВ 1,4 -БЕНЗОДИОКСАНА

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Abstract

The article presents the results of a study of the temperature dependence of the surface tension coefficient and the refractive index of 1,4-benzodioxane. Graphs of the temperature dependence of the coefficients σ and n have been constructed. Using the Sigma Plot analytical program, computer-mathematical models of the dependencies have been described in the form of equations. The regression equations of the models can be used in chemistry and medicine, where the 1,4-dioxane ring is used for the synthesis of its difficult-to-access derivatives.

Аннотация

В статье приведены результаты исследования температурной зависимости коэффициента поверхностного натяжения и показателя преломления 1,4 -бензодиоксана. Построены графики температурной зависимостей коэффициентов σ и n. Применяя аналитическую программу Sigma Plot описаны компьютерно-математические модели зависимостей в виде уравнении. Регрессионные уравнении моделей можно использовать в химии и медицине, где применяется 1,4 – диоксиновое кольцо для синтеза его труднодоступных производных.

Keywords: 1,4-benzodioxan, heating, temperature, surface tension, refractive index

Ключевые слова: 1, 4 - бензодиоксан, нагрев, температура, поверхностное натяжения, показатель преломления

Введение

Многие вещества применяются в фармакологии. Среди которых особое место занимают 1,4 -бензодиоксан и его производные, которые обладают гетероциклические 1,3-, или 1,4-, содержащие пяти- и шести-членные циклы, имеющие фармакологическими и биологически активными свойствами[1–6].

Бензо-1,4-диоксан (1,4-бензодиоксан) – это бесцветная жидкость слабим специфическим запахом. Хорошо растворяется в органических растворителях. В литературе встречается характеристики и применения многих производных бензо-1,4 -диоксана, как (Pyrroxanum)-гидрохлорид 6-(4-(3-фенилпирродинил-1) пропионил) – 1,4 -бензодиоксана который применяется в фармацевтике [7-9].

В химии 1,4-бензодиоксан применяется [9]:

- в синтезе гетероциклических соединений, полимерных соединений;
- в синтезе производных мочевины на основе 6-аминобензо-1,4-диоксана;

- в реакциях с применением 1,4 – диоксанового кольца, 5, 6 ,7 -тринитро – 1,4 -бензодиоксан под воздействием аммиака образует продукции расщипления и образуется 3, 4, 5 -тринитропирокатехин и этилдиамин;

- в перегруппировках аналитики используют для синтеза труднодоступных его производных. Например, при нагревание 5 – ацилокси – 1,4 -бензодиоксан в присутствии хлористого алюминия образует 6 -ацетил – 5 гидрокси – 1,4 бензодиоксан.

Из литературных источников [10 - 12] известно, что, при анализе производных 1,4 бензодиоксана обнаружены много биологически активные вещества которые успешно применяются в медицине.

В медицине 1,4-бензодиоксан успешно применяется:

- для синтеза лекарственных средств для повышения тонуса и при гипертонических кризисах, как фенилпирродинил -1, 1,4 -диоксан гидрохлорид и другие;

- для синтеза психотропных лекарствах, как бутероксан, который применяется для лечения отравлениях, а также артериальной гипертензии, алкогольной и опиатной абстинециях.

В аналитических исследованиях 1,4-бензодиоксан применяется:

- для разработки аналитических методов исследования применяется как стандартная вещество;
- для калибровки масс – спектрометров;
- для количественного анализа сложных многокомпонентных систем;
- в научных исследованиях для определения механизмов реакции и в изотопных исследованиях.

Хотя синтезированы много производные 1,4 -бензодиоксана и изучены их химические характеристики, но их оптико-реологические свойства в зависимости от температуры изучены недостаточно и желает уточнению.

В связи с этим нами исследована температурные зависимости оптических и реологических свойств 1,4-бензодиоксана.

Материалы методы исследования

Объектом исследовании является 1,4-бензодиоксан синтезированный учеными Института химии им. В. И. Никитина академии наук республики Таджикистан [13].

Исследования проводились в лаборатории «Теплотехника» физического факультета Таджикского государственный педагогический Университета имени С. Айни. Для измерения температурной зависимости коэффициента поверхностного натяжения (σ) и показателя преломления видимого света (n) применили комплексную установку по определению реологических и оптических характеристик жидкостей разработанной работниками лаборатории.

Комплексная установка по определению реологических и оптических характеристик жидкостей состоит из водяного термостата, заполненной трансформаторной маслом, электродвигателя, ртутного термометра, электронных весов, кварцевого поплавка, лампочки, пробирки, груши для вискозиметра, рефрактометра ИРФ -454 БН, капилляров для образования каплей исследуемых жидкостей, штатива, мультиметра UNI - T, UT71B, проводов для подключения мульти метра UNI - T, UT71B к компьютеру и ПЭВМ (Рисунок 1).

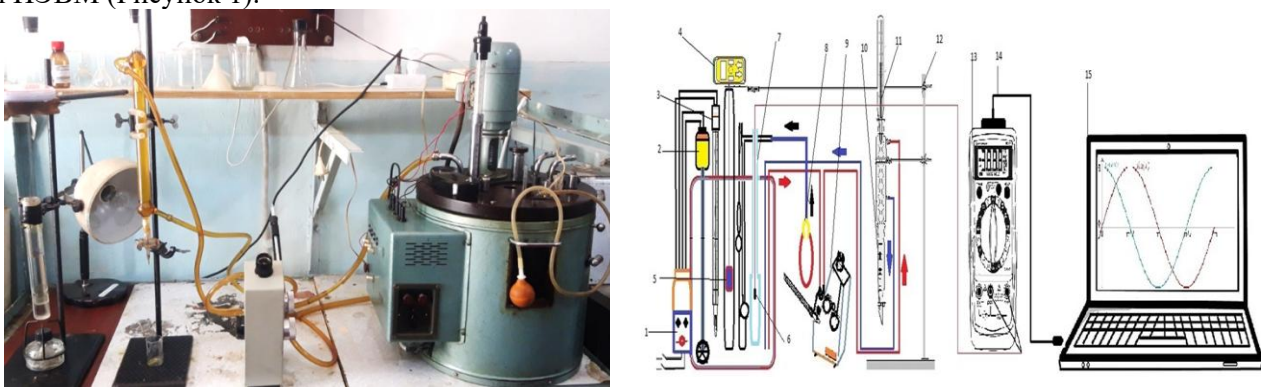

Рисунок 1 - Блок-схема комплексной установки по определению реологических и оптических характеристик жидкостей. 1-термостат водяной, 2- электродвигатель, 3- ртутный термометр, 4-электронные весы, 5-кварцевый поплавок, 6-лампочка, 7-пробирка, 8-груша для вискозиметра, 9-Рефрактометр ИРФ - 454 БН, 10-каппиляр для получении каплей, 11-ртутный термометр, 12-штатив, 13-мультиметр UNI - T, UT71B, 14- оптический провод для подключения мульти метра к компьютеру, 15-ПЭВМ

Принцип работы установки. Вискозиметр Освальда, пробирка для определения плотности методом гидростатического взвешивания, капилляр для получении каплей и предметный столик рефрактометра заправляется исследуемой жидкостью. Кварцевый поплавок устанавливают так, чтобы

не прикасались к стенкам пробирки, электронными весами определяют массу поплавка в исследуемой жидкости при комнатной температуре. Измеряется вязкость жидкости, коэффициент поверхностного натяжения и показатель преломления по известным методикам при комнатной температуры. Программируя мультиметр UNI - T, UT71B по времени подключаем режим нагрев. При фиксированных температурах (через 5 или 100 с.) определяется вязкость, коэффициент поверхностного натяжения и показатель преломления жидкости. Применяя программу Sigma Plot построят графики и рассчитывают коэффициенты регрессионных уравнении зависимостей.

Базой для поддержания температуры исследуемой жидкости является водяной термостат, заполненный трансформаторным маслом.

Прозрачными шлангами термостат подключен к рефрактометру ИРФ - 454 БН и накопителю капилляра для получения однородных по объему каплей. В начале, при комнатной температуре определяется коэффициент поверхностного натяжения и показатель преломления 1,4-бензодиоксана согласно методикам:

Коэффициент поверхностного натяжения 1,4-бензодиоксана

Коэффициент поверхностного натяжения 1,4-бензодиоксана определяется методом отрыва капели из капилляра. Образующиеся капли 1,4-бензодиоксан на наконечники капилляра непосредственно перед отрывом висят, при этом сила тяжести mg, действующая на каплю, уравновешивается силами поверхностного натяжения, $\sigma\pi D$. Пользуясь соотношением (1) определяется коэффициент поверхностного натяжения 1,4-бензодиоксана.

$$\sigma = mg/\pi D \qquad (1)$$

Массу одной капли 1,4-бензодиоксана определяют по общей массе 100 капель. Расчетная формула для вычисления коэффициента поверхностного натяжения имеет вид:

$$\sigma = \rho vg/\pi D100 \qquad (2)$$

Показателя преломления 1,4-бензодиоксана определяется рефрактометрией. Применен рефрактометр ИРФ - 454 БН.

Результаты исследовании и обсуждения

Измеренные значении коэффициента поверхностного натяжения и показателя преломления 1,4-бензодиоксана для видимого цвета от температуры приведена в таблице 1.

Таблица 1

Измеренные значения коэффициента поверхностного натяжения и показателя преломления 1,4-бензодиоксана

Измеряемые коэффициенты	Измеренные значении коэффициентов							
Температура, К	293	303	313	323	333	343	353	363
Коэффициент поверхностного натяжения, мН/м	35,12	34,87	33,00	29,43	29,07	26,03	23,70	20,70
Показатель преломления, n	1,549	1,547	1,54	1,538	1,53	1,514	1,483	1,457

Из полученных данных эксперимента построена графики зависимости коэффициентов от температуры. Зависимости коэффициента поверхностного натяжения и показателя преломления 1,4-бензодиоксана от температуры приведены на рисунке 2 и3.

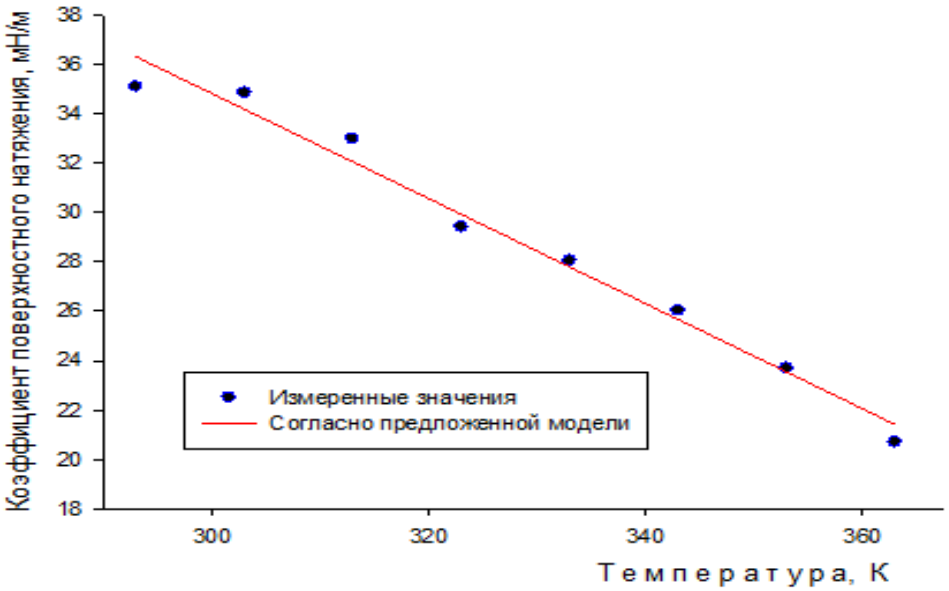

Рис.2. Зависимость коэффициента поверхностного натяжения 1,4-бензодиоксана от температуры

Как видно из графика повышения температуры 1,4-бензодиоксана сопровождается уменьшением коэффициента поверхностного натяжения. Уменьшение коэффициента имеет линейный характер. Его можно описать линейным уравнением. Уравнение имеет вид:

$$\sigma = \sigma_0 + at \qquad (1)$$

где, σ_0 = - 98,7837 и a = - 0,6395

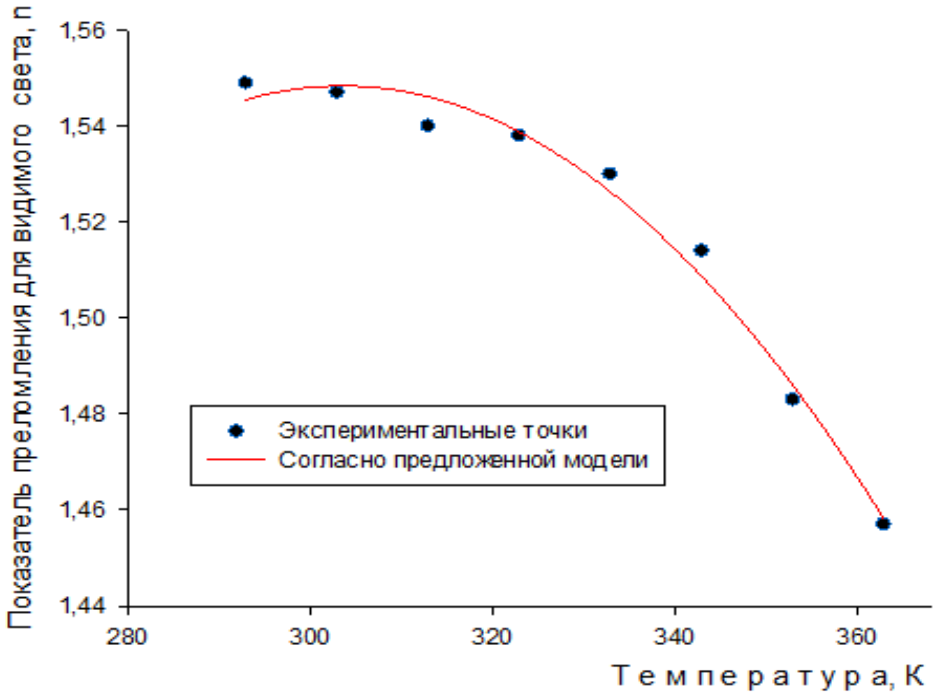

Рисунок 3 – Зависимость показателя преломления 1,4-бензодиоксана от температуры

Как видно из рисунков показатель преломления 1,4-бензодиоксана с повышением температуры умещается. Уменьшение можно описать параболической кривой (Модель зависимости). Применяя аналитическую программу «Сигма Плот» определены коэффициенты регрессионной уравнении предложенной модели.

Квадратическая зависимость

f = y0+a*x+b*x^2

y0 -2,4314 0,8105

a -0,0155 0,0466

b -7,6786E-005 2,5595E-005

Заключение

Анализируя полученные экспериментальные данные, можно заключить что уменьшения коэффициента поверхностного натяжения с повышением температуры обусловлен межмолекулярным взаимодействием молекул 1,4-бензодиоксана, что обусловливает нахождение молекул в связанном состоянии в жидкости. Потому при поверхностных молекулах1,4-бензодиоксана обладают избыточной потенциальной энергией, и потому объем жидкости при условии вакуума стремится принять идеальную сферическую форму, значит, такая форма имеет наименьшую потенциальную энергию.

Из-за избыточной потенциальной энергии молекулы 1,4-бензодиоксана находящихся на поверхности жидкости, находятся в своеобразной потенциальной яме, и чтобы их отделить от жидкости, нужно приложить определенную работу. При повышении температуры молекулы1,4-бензодиоксана получают кинетическую энергию, достаточную для разрыва межмолекулярных связей. В результате этого потенциальная энергия межмолекулярного взаимодействия уменьшаются, а это значит, что уменьшается и коэффициент поверхностного натяжения.

Литература

1. Goodman, L. Goodman & Gilman's Pharmacological Basis of Therapeutics / L. Goodman // New York: McGraw-Hill, 2011. – P. 2084.

2. Касьян, Л. Оксаазагетероциклы на основе аминоспиртов, эпоксидов и азиридинов: монография / Л.И. Касьян, В.А. Пальчиков, А.В. Токарь. – Днепропетровск: Изд-во ДНУ, 2012. – 644 с.

3. Jaouen, G. Bioorganometallics: Biomolecules, Labeling, Medicine / G. Jaouen. – Weinheim: Wiley-VCH, 2006. – 444 p.

4. Ahmed, B. Chemistry and Pharmacology of Benzodioxanes / B. Ahmed, H. Habibullah, S. Khan //Org. Chem. – 2008. – № 4. – P. 65–77. DOI: 10.1002/CHIN.200936265.

5. Pilkington, L. Synthesis and Biology of 1,4-benzodioxane Lignan Natural Products / L. Pilkington, . Barker // Royal Soc. Chem. – 2015. – № 32. – P. 1369–1388. DOI: 10.1039/c5np00048c.

6. Даукшас, В.К. 3-Фенил- или α-фенилзамещенные 2-алкил-аминометилбензо-диоксаны-1,4 /В.К. Даукшас, А.П. Ластаускас // ЖОрХ, сб. Биологически активные соединения. – 1968. –С. 286–290.

7. Ahmed, B. Chemistry and pharmacology of benzodioxanes/ B. Ahmed, S. Khan // Organic Chem. An. Indian J.- 2008, 4, 65-72.

8. 3. Pilkington L. Synthesis and biology of 1,4-benzodioxane lignan natural products / L. Pilkington, and D. Barker// Nat. Prod. Rep.- 2015, 32, 1369-1388.

9. 4. Achari B. Chowdhury – Perpectives on 1,4-benzodioxins, benzoxazines and their 2,3-dihydro derivatives / B. Achari, S. Mandal, P. Dutta // Synlett. 2004, №14, p. 2449-2467. Eng. Библ. 77. Обзор.

10. The Use of Stems in the Selection of International Nonprietary Names (INN) for Pharmaceuticalнатрия, -Substances. 2011, WHO

11. Straniero V., Casiraghi A., Fumagalli L., Valoti E. Chirality. 2018, 30, 943-950. doi 10.1002/chir.22968

12. Yin X., Huang Y., Chen Z., Hu Y., Tao L., Zhao :Dong X.-Q., and Zhang X. Org.Lett. 2018, 20, 4173- 4177. doi 10.1021/acs.orglett.8b01469

13. М.З. Турдиалиев, Синтез и химические превращения некоторых производных 1,4-бензодиоксана. Диссертация. Душанбе 2019.- 107 с.

Political sciences

CROSSING INTERESTS AND MOUNTAINOUS GEOGRAPHY. THE GEOPOLITICAL PARADOX OF AZERBAIJAN

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Abstract

Azerbaijan's geopolitical position is filled with paradoxes that create both significant opportunities and serious risks. The country is located in a complex mountainous terrain, which presents both obstacles and defensive advantages for the development of its transportation and energy infrastructure. While the mountainous areas provide natural defense benefits, they also pose substantial challenges for the security of energy pipelines and communication lines. At the same time, the mountainous geography played a crucial role in the Nagorno-Karabakh conflict, serving as a strategic advantage in military operations. In its foreign policy, Azerbaijan relies heavily on the concept of balance anda multivector approach, which serve as key diplomatic tools. In a region where the interests of major regional and global powers Russia, Turkey, Iran, and Western countries intersect, Azerbaijan pursues flexible and pragmatic diplomacy to protect its national interests. This strategy enables it to reduce security risks while creating new opportunities for economic development and regional integration. In the post-conflict period, one of Azerbaijan's main tasks is the socio-economic rehabilitation of the mountainous territories, reconstruction of infrastructure, and ensuring stability in the region. Geographic factors the challenges and opportunities presented by the mountainousterrainplay an important role in this process. The opening of new transport corridors and expansion of energy projects strengthen regional economic integration and further consolidate Azerbaijan's geopolitical position. Thus, Azerbaijan manages risks and maximizes opportunities through strategic maneuvering within its mountainous geography and complex geopolitical environment, acting as a key player for regional stability.

Keywords: Azerbaijan, geopolitical paradox, mountainous geography, regional interests, geostrategic position, South Caucasus, security, balanced policy, infrastructure security

Introduction

The news updated. The history of the Nubian Qafqaz region is characterized by historical histories, geographical backgrounds and geopolitical dynamics. For the commercial development of Azerbaijan they have low energy levels, they have the important transportation-transit system malik bir dövlət kimi qlobal diqqət market intelligence. In addition, they are characterized by the reliability of the relief system, due to their transportation, their infrastructure, their regional cooperation özünəməxsus geopolitics paradoxically. Armenia's recent developments in the central olan Dağlıq Qarabağ and beyond the border coğrafi xüsusiyyətləri bu paradoxun bariz nümunəsidir. Azerbaijan's religious interests in Russia, Iran, Turkey, China and Croatia have killed civil servants, and others are politically active balanced and practical black demand edit. By the end of 2020, the country will be able to rebuild the sonra region because of the Brazilian strategy of developing a successful missionary foundation actuality of the artwork. In addition, Azerbaijan's geopolitical position is being reassessed in the context of climate change, energy security, the stability of transport corridors, and the new security architecture being formed in the South Caucasus. For this reason, analyzing how mountainous geography plays a role in the country's foreign policy, defense strategy, and regional integration processes, as well as identifying the paradoxical challenges and opportunities created by this situation, is of particular scientific and strategic relevance.

A brief overview of the geopolitical location of Azerbaijan. The territory of the Republic of Azerbaijan is considered one of the important geopolitical nodes of the South Caucasus region - the Eurasian continent. This space is both an important transition zone connecting Asia and Europe, and the intersection of north-south, as well as east-west transport and energy corridors. Azerbaijan, bordering Russia in the north, Iran in the south, Armenia in the west, Georgia in the northwest and the Caspian Sea in the east, has access to the center of the Eurasian continent, and creates transit opportunities for relations with Central Asia and China via the sea route. This strategic location of Azerbaijan results in the geopolitical processes taking place in the region and in the world directly affecting its national security, economic development and foreign policy. In particular, its possession of energy resources (oil and natural gas) and its role as a bridge in transporting these

resources to Europe make it an important area of partnership and competition between the West and Russia. At the same time, historical, cultural and economic relations with Iran and Turkey also increase Azerbaijan's regional geopolitical weight. At the same time, the fact that up to 20 percent of the country's territory remained under occupation for many years (from the 1990s to 2020), especially the Nagorno-Karabakh conflict, further complicated the problems of stability and security in Azerbaijan's geopolitical environment. Against the background of new realities emerging after the 2020 Patriotic War, Azerbaijan's geopolitical position has begun to acquire more strategic importance not only for regional, but also for international power centers. In this context, the geopolitical space in which Azerbaijan is located acts as both an opportunity and a source of risk. In order to protect its interests in this complex environment, the country is obliged to pursue a policy based on balanced diplomacy, multilateral cooperation, and sustainable security strategies.

Political and military significance of mountainous geography. Mountainous areas act as a geographical formation of special importance both politically and militarily in world history and in the system of modern international relations. While this relief form, on the one hand, can be used as a natural defense line, on the other hand, it creates serious obstacles in the construction of infrastructure and socio-economic development. In the case of Azerbaijan, the effects of mountainous geography have been more pronounced. Approximately 60 percent of the territory of Azerbaijan is made up of mountainous and foothill areas, which highlights the military-strategic advantages and political consequences of mountainous terrain in the country's security policy. In particular, the mountainous terrain in the Karabakh region - impassable valleys, difficult mountain roads and high position advantages - formed the basis for military fortification in the territories occupied by Armenia for a long time. This geography created a defensive advantage for Armenia and limited Azerbaijan's counterattack capabilities [3].

During the 2020 Patriotic War, combat operations in mountainous areas proved how difficult this geography is, but a plane that can be conquered with proper planning and technological superiority. In particular, the capture of heights such as Sugovushan, Murovdag, and Shusha had a serious impact on both the course of operations and political outcomes. Holding a superior position in mountainous areas both ensures strategic control and creates a basis for negotiations on favorable diplomatic terms. From a political point of view, mountainous areas can be the center of separatism and ethnic conflicts. The geographical and informational isolation of ethnic minorities living in mountainous areas from the central government sometimes creates the basis for their claims to self-determination. The Nagorno-Karabakh conflict has also highlighted the contradictions between international law and territorial integrity in this context. At the same time, the border location of mountainous regions poses additional risks in regional geopolitics and determines the priority direction of defense strategies. At the same time, mountainous geography plays an important role in border defense, visual and technological surveillance advantages, and timely detection of potential threats. It is for this reason that Azerbaijan has paid special attention in recent years to the construction of new posts and surveillance systems on mountainous bordersespecially along the border with Armenia. Consequently, mountainous geography is a strategic factor of irreplaceable importance in both the military security concepts of Azerbaijan and the formation of its political position. The presence of opportunities as well as the challenges created by this geography necessitates the maintenance of a wise balance in the country's defense and foreign policy.

Azerbaijan's unique position as a place where the interests of regional powers intersect. The geostrategic location of Azerbaijan The South Caucasus region has historically and in modern times acted as one of the sensitive zones where the interests of regional and global powers intersect. Bordered by the Russian Federation in the north, the Islamic Republic of Iran in the south, Armenia and Turkey in the west, and the Central Asian states through the Caspian Sea in the east, Azerbaijan plays the role of a bridge between Europe and Asia. This geographical location creates both opportunities and serious threats for it in a geopolitical sense. The main reason for Azerbaijan's unique position is the important energy and transport corridors it is located on. Through the Baku-Tbilisi-Ceyhan (BTC) oil pipeline, the Baku-Tbilisi-Erzurum (BTE) gas pipeline, and the Trans-Anatolian Gas Pipeline (TANAP), Azerbaijan has become the main country delivering the energy resources of the Caspian basin to the West. In addition, the Baku-Tbilisi-Kars (BTK) railway and the Middle Corridor initiatives are further strengthening Azerbaijan's role as a transit country [22].

This strategic position increases the interests of regional powers in Azerbaijan: for Russia, Azerbaijan is important both in terms of maintaining its sphere of influence in the South Caucasus and in the context of access to Central Asia. Moscow seeks to maintain balanced relations with Azerbaijan, especially in terms of cooperation on energy transport and security issues.

Although Iran has religious, historical and ethnic ties with Azerbaijan, it pursues a cautious policy in relations with Baku due to both competition in the energy market and relations with Israel. At the same time,

the Azerbaijani population living in the southern region of Azerbaijan is also considered an internal political factor for Tehran.

Turkey, in addition to being Azerbaijan's main strategic ally, has established a deep partnership with it within the framework of both military cooperation and energy and transport projects. Turkey's strengthening in the South Caucasus is carried out through Azerbaijan.

For the European Union and the United States, Azerbaijan is important as an alternative energy source and a guarantor of regional stability. Energy cooperation with Azerbaijan is of vital importance for Europe, especially in order to reduce its energy dependence on Russia.

The People's Republic of China also considers Azerbaijan as a key part of the Middle Corridor within the framework of the "One Belt, One Road" initiative and is interested in expanding infrastructure cooperation with Baku. These intersecting interests necessitate Azerbaijan to pursue a geopolitical balance policy. Baku seeks to stay out of conflicts and maximize its national interests by cooperating with different powers at the same time. However, this position also requires a delicate balance. Because rapprochement with one power is met with concern by other powers, which can lead to diplomatic pressures, economic risks, and security challenges [14].

Relief features of the Karabakh region and conflict risks. The Karabakh region is one of the strategically important areas in the geopolitical environment of Azerbaijan, with a complex mountainous terrain. The Lesser Caucasus mountain range forms the main part of the region; here are mountains ranging in height from 1000 to 3000 meters, deep valleys, steep slopes and difficult mountain passes. These natural relief forms have been one of the main factors in Karabakh becoming an important place from a political and military point of view. The mountainous terrain provides serious advantages, especially in terms of defense and control. Positions located at high altitudes are important in terms of both visual observation and fire superiority during any conflict. During the occupation of Karabakh by the Armenian armed forces in the early 1990s, they were able to easily control the settlements of Azerbaijan located below by using these mountainous areas. The difficulty of the terrain has also significantly limited the military counter-offensive potential of Azerbaijan [6]. This geographical condition acts as a factor structuring the risks of conflict. The geographical isolation of the population living in the mountainous region from the central government and the long-term nature of this isolation create fertile ground for the development of ethnic separatism and separatist tendencies. The Karabakh conflict, which began in 1988 and lasted for nearly 30 years, was rooted not only in ethnic conflict, but also in institutional divisions caused by geographical isolation. The relief factor limited humanitarian and infrastructure access to the territory, making it difficult to restore political control. The successful military operations carried out by Azerbaijan during the 2020 Patriotic War showed how the advantages of relief can play a strategic role not only in defense, but also in offensive planning. In particular, the Shusha operation, which was carried out by entering the city on foot from mountainous and forested areas, is considered an example of the application of innovative military tactics in mountainous terrain. In addition, the capture of the Murovdag range changed visual and communicative control in the region. Currently, the mountainous terrain of Karabakh remains a geopolitical risk factor even in the post-conflict period. The forested areas and difficult-to-access areas in the mountains are risky in terms of acts of sabotage and the threat of mines. At the same time, the restoration of civil infrastructure and the implementation of transport and communication projects in this terrain are also technically and economically complex. As a result, the mountainous terrain of Karabakh has played a decisive geographical framework for both the beginning and continuation of the conflict, as well as the process of its resolution. This geographical factor continues to play an important role not only in terms of military and security, but also in shaping decisions on social reintegration, economic development and the future status of the region.

Impact of mountainous areas on transport and infrastructure projects Challenges:

Difficult terrain and terrain complexity: Construction work (roads, bridges, tunnels, etc.) in mountainous areas is more difficult and expensive. Ups and downs, steep slopes and the risk of landslides complicate project planning.

Earthquake and landslide risk: Landslides and seismic activity are more likely in mountainous areas, which requires the construction of structures with more robust and expensive technologies. Climatic conditions: Snow and frost can make roads impassable in winter. This increases the intensity of maintenance and repair work.

Disconnection and isolation: There are few roads connecting villages and cities in mountainous areas, and these areas are sometimes isolated from main transport lines for long periods of time.

Advantages: Tourism and ecotourism opportunities: When infrastructure is developed, mountainous areas become attractive for tourism, which has a positive impact on the local economy. Access to water

resources: Water basins located in mountains create favorable conditions for the construction of hydroelectric power plants and water supply.

Advantages and challenges of mountainous terrain in terms of defense and security

Advantages: Natural defense barrier: Mountainous areas make it difficult for the enemy to advance with military equipment and manpower. This relief condition creates a natural advantage for defense.

High observation points: Mountain peaks are ideal places for strategic control and observation. The opponent's movements can be determined in advance.

Area recognition advantage: Better adaptation of the local population and army units to mountain conditions can create an asymmetric advantage against the enemy.

Difficulties: Communication and supply problems: The supply of troops (food, weapons, medical aid, etc.) in mountainous terrain becomes difficult. Long distances and impassable roads slow down this process. Planning of operations: It is difficult to conduct large-scale military operations in mountainous terrain. The mobility of military equipment is limited.

Impact of weather conditions: Snowy, foggy and frosty weather conditions complicate both military and observation activities.

Intersecting regional and global interests. A map of geopolitical competition in the South Caucasus.

The South Caucasus – this strategic region, home to Azerbaijan, Georgia and Armenia – is in the sphere of interest of both regional and global powers. The region's geostrategic position, energy resources, transport corridors and security issues increase its weight in the system of international relations. The interests of several power centers clash and intersect here.

Russia: Maintaining its geopolitical influence: Russia wants to maintain its hegemony in the post-Soviet space and control the South Caucasus as part of its "near abroad" strategy

Instruments of influence within the CSTO and CIS: Russia is a military ally of Armenia and maintains a military base in this country. It seeks to maintain its military presence in the region. Peacekeepers and Karabakh: The Russian peacekeeping contingent in Karabakh is one of Moscow's instruments of control in the region [1].

Opposition to energy and transport alternatives: Russia is skeptical about the development of alternative energy and transport routes such as the Trans-Caspian and Southern Gas Corridors, as these projects weaken its gas exports to Europe.

Iran: Border security and separatism concerns: Iran is closely monitoring the Turkic-speaking population factor in the South Caucasus, especially in relation to Azerbaijan, as well as the issue of national unity. Cautious attitude towards the Zangezur corridor: Iran wants to maintain its relationship with Armenia and create a balance against the further rapprochement of Turkey and Azerbaijan through the corridor to be opened between Nakhchivan and Azerbaijan. Access routes to Afghanistan and Central Asia: Iran sees the South Caucasus as an access point to Central Asia and the Black Sea and wants to play a role in the North-South Transport Corridor.

Turkey: Bridge to the Turkic world: Turkey wants to establish integration and cooperation with Central Asia in the South Caucasus, especially through Azerbaijan. The Zangezur corridor is of strategic importance in this regard.

Military and diplomatic cooperation: The Turkey-Azerbaijan alliance (2021 Shusha Declaration) shows Ankara's growing military and political weight in the South Caucasus.

Participation in energy projects: Through projects such as TANAP and TAP, Turkey has become an important transit country in Europe's energy security.

Soft power: Turkey is also trying to increase its influence in the region through cultural, educational and religious ties.

Western countries (US and EU): Energy security: The European Union sees Azerbaijani natural gas as an alternative energy source to Russia. The Caspian Sea and the Southern Gas Corridor are of particular importance in this regard.

Democracy and human rights agenda: The US and EU are interested in promoting political reforms and the rule of law in the region.

Influence through Georgia: Since Georgia has chosen the path of integration with the West, it has established close cooperation with NATO and the EU; this increases the West's influence in the region.

Countering Russian influence: The West, especially the United States, is trying to weaken Russian influence and is offering various economic and military assistance for this. The South Caucasus is a point of intersection of permanent interests, competition, and strategic cooperation. Stability and security in this region are impossible without a balanced foreign policy, pragmatic diplomacy, and multilateral cooperation.

Azerbaijan's location on energy and transport corridors. Strategic clash and diplomatic games of great powers.

Azerbaijan: Transition Center and Strategic Bridge. Geographically, Azerbaijan is located at a strategic transition point between Europe and Asia. The country is at the intersection of both East-West and North-South transport and energy corridors, and has significant geopolitical value for regional and global powers. Therefore, Azerbaijan acts as an energy exporter on the one hand and a transit country on the other.

Energy Corridors and Power Struggle. Azerbaijan's main energy projects: Baku-Tbilisi-Ceyhan (BTC) oil pipeline. Baku-Tbilisi-Erzurum gas pipeline. Southern Gas Corridor (TANAP-TAP). Baku-Supsa oil pipeline. These projects create direct access to Western markets by bypassing Russia, which is of strategic importance for Western states (especially the EU and the USA) in terms of energy security.

Conflicting interests: Russia: Sees these corridors as a threat to its energy hegemony. It wants to regain control over the South Caucasus and limit the access of Azerbaijani gas to Europe. The West (EU, USA): Supports Azerbaijan as a reliable partner to reduce the risk of Russian energy blackmail, and tries to ensure the sustainability of these corridors through various financial and diplomatic means.

Iran: Since it wants to gain a competitive transit and energy role, it takes a neutral and sometimes critical position towards Azerbaijan's energy projects directed towards the West.

Turkey: Within the framework of its strategic alliance with Azerbaijan, it has become the main transit country for these projects. Ankara is strengthening its relations with Baku to increase both its energy and geopolitical power.

Transport Corridors and Diplomatic Maneuvers. Main projects: Middle Corridor (Trans-Caspian International Transport Route): China–Kazakhstan–Caspian–Azerbaijan–Georgia–Turkey–Europe line.

Zangezur Corridor (potential): Land connection between Azerbaijan and Nakhchivan via Armenia, a new road connecting the Turkic world.

North-South Transport Corridor: India-Iran-Azerbaijan-Russia line.

Geopolitical competition: China: Intends to strengthen access to Europe via Azerbaijan with the “One Belt, One Road” initiative.

US and EU: By supporting the Middle Corridor, they want to both maintain economic ties with China and build alternatives beyond Russian control.

Russia: Is cautiously monitoring Azerbaijan's activity in the Middle Corridor and the Zangezur corridor project, as it stimulates trade flows beyond its control

Iran: Does not want Armenia's economic role to weaken through the Zangezur corridor. At the same time, it is trying to make the North-South corridor passing through its territory more important.

Diplomatic Games and Strategic Balance. Azerbaijan, pursuing an independent, balanced and multilateral foreign policy against the backdrop of these conflicting interests, has: turned energy diplomacy into a geopolitical tool; prevented its irritation by maintaining cautious cooperation with Russia; changed the regional balance of power through a strategic partnership with Turkey; played an important role in European energy security by strengthening energy cooperation with the West. The energy and transport corridors in which Azerbaijan is located increase its not only economic, but also political and geopolitical weight. However, this also intensifies the diplomatic competition of powers with overlapping interests in the region. Azerbaijan is trying to protect its interests in this complex game with agile diplomacy and pragmatic policy.

In the Context of the Concept of “Balance Policy” and “Multivector Approach”. Geopolitical Paradoxes: Why is Azerbaijan “Weak but Necessary”? Azerbaijan is located in one of the most complex geopolitical spaces of the South Caucasus, on the line where the interests of the great powers (Russia, Iran, Turkey, the West) intersect. This increases both the opportunities and risks of Azerbaijan. The main points of geopolitical paradoxes are: the desire to cooperate with the West in the same geography as Russia; border neighborhood with Iran, but a strategic alliance with Turkey; peacekeeping Russian presence after the Karabakh conflict, but close energy cooperation with Europe; being a member of the Islamic world as a Muslim country, but having high-level military-security relations with Israel. Such contradictory positions turn Azerbaijan into a “country of geopolitical paradoxes” and force it to make agile diplomatic maneuvers.

Balance Policy: It occupies an important place in the foreign policy doctrine of Azerbaijan. This concept implies that Azerbaijan maintains relations with several powers at the same time without violating them. Main features: Security and economic cooperation with Russia (close relationship without joining the CSTO); Strategic alliance with Turkey, but without blocking against the West; Cooperation with the European Union and the US in the field of energy and human rights, without straining relations with Russia and Iran; Security and defense cooperation with Israel, while avoiding open confrontation with Iran. The policy of balance, especially after the Karabakh war in 2020, has become even more relevant. Azerbaijan has tried to maintain its independent position without fully entering the sphere of influence of either Russia or the West.

Multivector Approach: Parallel Relations and Balance of Interests. Multivector policy also implies the establishment of parallel and balanced relations with various political, economic and military blocs. This model is also applied in other post-Soviet countries such as Kazakhstan and Uzbekistan, but in the case of Azerbaijan this policy is more active and flexible.

The main pillars of Azerbaijan's multivector approach: Bridging the East-West: Connecting Europe and Asia through the Middle Corridor, the Southern Gas Corridor; Active participation in the Turkic States Organization, as well as leadership in the Non-Aligned Movement (Azerbaijan chaired it in 2019–2023); simultaneous high-level relations with Israel and Pakistan – one as an ally from the Jewish and the other from the Muslim world; cooperation with the United States, China, Russia and the European Union within the framework of separate interests. This approach expands Azerbaijan’s possibilities for maneuver both regionally and internationally and makes it a more agile actor.

Risks and Challenges. Weak balance: risk of tension in relations with one of the great powers; coming under pressure in the Russia-West and Iran-Israel confrontations; the need for flexible adaptation to geopolitical changes. Azerbaijan’s foreign policy doctrine is built on “geopolitical realism” and the ability to maneuver in a multipolar system. A balance policy and a multivector approach are effective mechanisms for Azerbaijan to conduct an independent foreign policy, maintain regional stability and ensure its economic interests.

Azerbaijan's cooperation with Russia, partnership with the West and alliance with Turkey. Cooperation with multiple powers at the same time is Azerbaijan's maneuvering field

A unique feature of Azerbaijan's foreign policy is that the country: continues military-political and economic cooperation with Russia; establishes energy, economic and political dialogue with Western countries; and implements a strategic alliance and military-tactical cooperation with Turkey. These three directions are managed simultaneously, without conflicting with each other. This is the main reason why Azerbaijan is perceived as a country of geopolitical paradoxes.

Cooperation with Russia. After the Karabakh conflict ended with a trilateral statement on November 10, 2020, Russia became responsible for ensuring security in the region through peacekeeping forces. There is also cooperation between Azerbaijan and Russia in the field of trade and energy. However, Azerbaijan does not join the CSTO, which serves to protect independence and pursue a policy of balance. Caution and balance are maintained in relations with Russia, and the risks of conflict are minimized.

Partnership with the West. Azerbaijan attaches great importance to energy cooperation with the West, especially the European Union and the United States (such as the Southern Gas Corridor project). Western partners emphasize Azerbaijan's key role in energy security and provide it with economic support. In addition, there is also a dialogue in the political sphere, but Azerbaijan's cooperation with Russia sometimes creates difficulties for the West.

Alliance with Turkey. Azerbaijan and Turkey have a strong strategic alliance based on the principle of "one nation, two states". Turkey's military-diplomatic support in the 2020 Karabakh war played a significant role in Azerbaijan's victory. With the Shusha Declaration signed in 2021, the two countries further strengthened military-political cooperation. Turkey is Azerbaijan's most important partner in energy and transport corridors in the region.

Zangezur corridor issue: The Zangezur corridor project, planned and promoted by Azerbaijan, aims to connect Nakhchivan with the main part of the Republic of Azerbaijan. The fact that this corridor passes through Armenian territory and its importance for the regional transport infrastructure creates a number of geopolitical difficulties. Russia and Iran have expressed concerns about the corridor, as it could weaken their transport and economic influence in the region. Turkey and Western countries, on the other hand, see the opening of the Zangezur corridor as an increase in regional integration and trade. Azerbaijan, pursuing a policy of balance in this matter, takes into account the interests of regional powers and promotes its own national interests.

Post-Karabakh period: After the 2020 war, Azerbaijan has restored its territorial integrity, which has strengthened its international status. At the same time, the presence of Russian peacekeepers is a diplomatic factor in ensuring peace in the region. Azerbaijan also ensures its security and development by strengthening its relations with the West and Turkey. This situation is a manifestation of Azerbaijan's balanced and multidirectional foreign policy. Azerbaijan's simultaneous cooperation with Russia, the West and Turkey allows it to turn the complex geopolitical paradoxes of the region into diplomatic realities. This is an important part of the country's strategy to protect its national interests, ensure regional security and effectively use geopolitical pressures.

Southern Gas Corridor and TANAP Project pass through mountainous areas. The impact of mountainous geography on energy corridors. The mountainous terrain of the South Caucasus, where

Azerbaijan is located, creates both difficulties and opportunities in the implementation of energy projects. Mountainous zones: Increase construction and maintenance costs; Strengthen project safety measures due to geological risks and natural disasters (landslides, earthquakes, snowfall); At the same time, this relief provides a strategic advantage for the protection of energy pipelines in terms of security, as mountainous terrain facilitates defense.

Southern Gas Corridor and TANAP Project. The Southern Gas Corridor is a strategic route that delivers gas from Azerbaijan's Shah Deniz gas field to Europe via Turkey. TANAP (Trans Anatolian Natural Gas Pipeline), which is part of this corridor, passes through Turkey. The project passes most of its length through mountainous and foothill zones. This creates engineering difficulties due to the complex relief of the mountains and high relief variability. Harsh climatic conditions and geographical obstacles in the regions through which the gas pipeline passes increase the time and cost of construction work. The project provides safe passage in mountainous terrain through special technologies, tunnels and bridges.

Security and Strategic Importance. Defense Advantages of Geographical Barriers: Mountainous areas play a natural barrier role in the defense of energy corridors. This is especially important in regions with high military and terrorist risks. Security Service and Control: Corridors located in mountainous areas are protected by special observation posts and technological control means. Role in Regional Stability: The Southern Gas Corridor and TANAP project strengthen regional cooperation and integration, contribute to ensuring energy security between Azerbaijan, Turkey and Europe.

Challenges and Obstacles. Natural Disasters and Technical Risks: Landslides, earthquakes and severe weather conditions in mountainous areas can threaten the continuity of the project.

Geopolitical Risks: Control and security issues over energy corridors depend on regional political tensions.

Engineering and Logistics Challenges: High technological and financial resources are required to lay and maintain a gas pipeline in mountainous conditions. The Southern Gas Corridor and TANAP project are at the heart of Azerbaijan's energy diplomacy and are among the strategic projects being implemented in mountainous regions. These projects are of great importance in terms of both economic benefits and regional security. Although mountainous terrain creates difficulties in the implementation of projects, its strategic advantages, especially in the field of defense and security, play an important role.

Impact of Mountainous Terrain: Physical Challenges: The construction and maintenance of energy pipelines, power lines, and communication networks in mountainous areas is more complex and expensive. The uneven terrain increases the difficulty of maintenance.

Natural Disaster Risk: Natural phenomena such as landslides, floods, earthquakes, and snowfall increase the likelihood of infrastructure damage in mountainous areas.

Security and Monitoring Challenges: Mountainous terrain makes observation, technical control, and defense difficult. This poses risks, especially in the protection of critical energy and communication lines.

High Defense Strategic Potential: At the same time, mountainous terrain plays the role of a natural defense barrier, making it difficult for the enemy to directly attack energy and communication infrastructure.

Mountainous Nature of the Border and Risks. Long and Difficult to Cross the Border Line: There are many mountainous zones on the Armenian-Azerbaijani border, which makes effective border control difficult.

Military Obstacles and Defense Advantages: Although mountainous areas give the parties a natural advantage for defense, they also increase the risk of the edges of the border remaining uncontrolled.

Security Risks of Mountainous Zones. Deficits and Border Violations: Attempts by separatist and terrorist groups using the terrain to cross the border are possible.

Difficulty of Military Operations: Although the mountainous terrain limits the movement of troops, this is not an obstacle for modern military technologies and small special forces.

Vulnerability of Infrastructure to Attacks: The proximity of energy and communication lines along the border increases the risk of being a potential target.

Strengthening Border Security. Technological Surveillance Systems: Drones, satellite surveillance and other modern technologies are used in border control.

Engineering and Technical Measures: The placement of observation posts along the border and the construction of defense lines are being strengthened.

Diplomatic and Military Cooperation: It is important to activate diplomatic channels to ensure peace and stability in the region. The mountainous terrain creates both risks and opportunities for the security of energy and communication infrastructures. Along the border with Armenia, this relief has natural defensive advantages, but there are also factors that make it difficult to effectively protect the border. Taking these

paradoxes into account, technological and diplomatic measures are at the forefront of Azerbaijan's security policy.

Reasons for Nagorno-Karabakh Becoming the Center of the Conflict. Geographical Features and Strategic Location. Mountainous terrain and favorable defensive positions: The Karabakh region has a mountainous and complex terrain, which makes defensive and offensive operations difficult from a military perspective. The mountainous areas have been the focus of attention of the parties in the conflict, creating a strategic advantage and obstacle.

Geographic isolation: The geographical location of Karabakh and the limited communication links have isolated the region to a certain extent from other parts of Azerbaijan and Armenia, both economically and administratively. This has created conditions for the emergence of separatist tendencies.

Ethnic and Historical Factors. Ethnic composition: The demographic composition of the population of Karabakh has changed at various times throughout its history. During the Soviet period, Armenians were the majority in the region, which laid the foundation for ethnic conflicts in the region. Historical claims: Both peoples claimed that Karabakh belonged to them. These claims led to the escalation of the conflict over control of the territory.

Administrative Borders of the Soviet Union and the Isolation Effect. Establishment of the Nagorno-Karabakh Autonomous Oblast (1923): The Soviet government granted Nagorno-Karabakh the status of an autonomous oblast within the Azerbaijan SSR, paving the way for increased ethnic and political conflicts.

Border and governance issues: Even during the Soviet era, central government control over the region was weak, and autonomous status paved the way for separatism.

Economic and Social Factors. Isolated economy: The mountainous and difficult terrain limited economic development, which increased social discontent.

Resource management: Disputes over the division of natural and economic resources in the region are part of the conflict.

International and Regional Factors. Collapse of the Soviet Union: The weakening of the Soviet regime in the late 1980s exacerbated ethnic conflicts.

International law and recognition of borders: Azerbaijan bases its territorial integrity on its territorial integrity, while Armenia bases its right to self-determination on the Armenian population.

Interests of regional powers: The interests of Russia, Iran, Turkey and Western countries in the region further complicate the conflict. The complex geographical, ethnic and historical features of Nagorno-Karabakh are one of the main reasons why it has become the center of the conflict. Geographical realities, administrative decisions inherited from the Soviet era and regional-political factors have combined to turn this region into a disputed and strategically important zone

The Impact of Geographical Factors on War and Peace Processes. Security and Defense Positions: Mountainous and complex terrain determine defense and attack strategies in military operations. Mountainous areas, while being favorable for defense, create difficulties for attack and transportation.

Territory Control and Strategic Locations: Important geographical heights, control points, and transport corridors become focal points of conflict.

Resource Distribution: Geographical factors play a role in the distribution of natural resources and economic opportunities, which is one of the causes of conflict.

Population Distribution and Ethnic Structure: The ethnic composition of the population in geographical areas increases the potential for conflict, especially in border and restricted areas.

Isolation and Communication: Mountainous and inaccessible areas complicate communication and transportation, as well as restrict the flow of information in the conflict zone.

Changes in the Role of Geography in the Post-Conflict Era. Territory Management and Reconstruction: Geographical factors play an important role in the post-conflict recovery of territories, reconstruction of infrastructure and opening of transport routes. In mountainous areas, these works are more difficult and require a long time.

Reorganization of Security Spaces: Geographical conditions are taken into account for the deployment of peacekeepers and border control. Mountainous terrain provides a strategic advantage in the deployment of security points.

Regional Cooperation and Development: In the post-conflict phase, geographical position plays a key role in the restoration of economic and transport relations. The creation of new corridors and the expansion of communication networks accelerate the integration of the region. Demographic Changes: As a result of the conflict, the return of displaced populations and internally displaced persons is organized in accordance with geographical realities, which ensures socio-political stability. Geographical factors play a decisive role in the formation of war and peace processes. While during the conflict period these factors determine military

strategies and the intensity of the conflict, in the post-conflict period geography affects the effectiveness of economic, social and security measures. Azerbaijan's strategy of maneuvering and developing in accordance with geographical conditions in the post-Karabakh period is the basis for the country's lasting stability.

Conclusion.

Azerbaijan's complex mountainous geography and strategic location are key factors in both conflict and peace processes. Although the mountainous terrain creates defense and security advantages in military operations, it also poses serious challenges in terms of protecting energy and communication infrastructure.

Against the backdrop of the conflicting interests of major powers in the region, such as Russia, Turkey, the West, and Iran, Azerbaijan is pursuing a policy of balance and a multivector approach to protect its national interests and gain broad geopolitical maneuvering opportunities. The role of geographical factors in the Karabakh conflict and its post-conflict phase is crucial in shaping Azerbaijan's regional integration, security, and economic development strategies. In this regard, Azerbaijan continues to strengthen its geopolitical position through agile diplomacy, strategic energy and transport projects, as well as military-tactical steps that ensure its security. The complex geopolitical space in which Azerbaijan is located presents both risks and opportunities. This paradox is a result of its intersecting interests with regional powersRussia, Turkey, Iran, and the West.

In terms of risks, Azerbaijan's foreign policy is affected by great power competition and regional tensions. This can create difficulties in security and sovereignty issues, as well as lead to economic and political pressures.

In terms of opportunities, Azerbaijan pragmatically benefits from this complex situation with a balancing policy and a multivector approach. The country strengthens its geopolitical position through energy and transport corridors, increases regional integration and diplomatic maneuvering opportunities.

Thus, Azerbaijan's geopolitical paradox creates rich opportunities for both protecting its national interests and acting as an active player at the regional and global levels. Mountainous terrain is both a source of isolation and strategic advantage. On the one hand, complex and difficult-to-pass mountainous areas lead to the isolation of the region, limiting communication and transportation, which can create obstacles to socio-economic development. On the other hand, mountainous terrain provides important strategic advantages in terms of defense and security. These areas allow for the strengthening of defensive positions in military operations and the restriction of the movement of enemy military forces. As a result, mountainous geography occupies an important place in Azerbaijan's regional security and development strategies, both as a challenge and an opportunity.

Balancing Intersecting Interests and Azerbaijan's Diplomatic Approach In the region where Azerbaijan is located, the interests of major powers such as Russia, Turkey, Iran and the West intersect and sometimes clash. In order to protect national interests and ensure regional stability in this complex geopolitical environment, Azerbaijani diplomacy must pursue a flexible, pragmatic and balanced policy. This requires both cooperation with regional powers based on mutual respect and commitment to international law and multi-vector relations from Azerbaijan. With diplomatic maneuvers, the country both minimizes security risks and expands its economic and political opportunities. As a result, Azerbaijan's successful foreign policy is based on the ability to create a balance between intersecting interests and dynamically protect national interests. The geopolitical paradox of Azerbaijan is a source of both risk and opportunity. Mountainous geography sometimes provides isolation, sometimes provides strategic advantage, In order to create a balance between intersecting interests, Azerbaijani diplomacy must demonstrate a more flexible and pragmatic approach

Literature

1. Əliyev, İ. (2022). Azərbaycanın enerji diplomatiyası və regional inteqrasiya. Bakı: Elm Nəşriyyatı.
2. Cornell, S. E. (2001). Small Nations and Great Powers: A Study of Ethnopolitical Conflict in the Caucasus. Richmond: Curzon Press.
3. Cornell, S. E. (2011). Azerbaijan Since Independence. M.E. Sharpe
4. Cornell, S. E. (2021). The Geopolitics of the South Caucasus after the Second Nagorno-Karabakh War. Middle East Institute. https://www.mei.edu
5. Cohen, S. B. (2003). Geopolitics of the World System. Rowman & Littlefield
6. De Waal, T. (2003). Black Garden: Armenia and Azerbaijan through Peace and War. New York University Press.
7. Gafarova, S. (2023). Regional cooperation and peacebuilding in the South Caucasus. Baku Research Papers, 5(1), 43–59.
8. Keddie, N. (2022). *Iran's Strategic Interests in the South Caucasus*. Middle East Journal, 76(3), 345–362.

9. Kortunov, A. (2018). Energy Diplomacy in the South Caucasus. Energy Policy Review, 45(2), 204–219.

10. Rahimi, M. (2023). "Iran's Foreign Policy in the Caucasus: Challenges and Responses." *Journal of Eurasian Studies*, 14(1), 112–129

11. Rauf M. (2023). Azərbaycanın diplomatik strategiyaları və çoxvektorlu xarici siyasət kursu. Bakı: Elm və Təhsil.

12. Ismayılov, E. (2020). "Dağlıq Qarabağın relyefi və münaqişənin hərbi-siyasi aspektləri", Geosiyasət və Müasir Təhlükəsizlik, 6(2), 34-47.

13. İsmayılov, E. (2022). "Azərbaycanın dağlıq relyefinin təhlükəsizlik siyasətinə təsiri", Geosiyasət və Strategiya, 14(3), 45-61.

14. Ismayılov, E., & Papava, V. (2010). A New Concept for the Caucasus. Center for Strategic Studies.

15. Heydər Əliyev. (1999). Azərbaycanın müstəqilliyi və xarici siyasəti. Bakı: Azərbaycan Dövlət Nəşriyyatı.

16. Hunter, S. (2017). The Transcaucasus in Transition. Routledge

17. Məmmədov, E. (2020). "Cənubi Qafqazda geosiyasi maraqlar və Azərbaycan siyasəti". Beynəlxalq Münasibətlər Jurnalı, 15(3), 45–62.

18. Zaman, M. Q. (2020). The Role of Transit Corridors in Enhancing Azerbaijan's Geopolitical Position. Central Asian Survey, 39(4), 556–572.

19. Smith, A. (2021). *The South Caucasus and the Limits of Western Influence*. European Foreign Affairs Review, 26(4), 521–537

20. Smith, J. (2018). Multivector Foreign Policy Strategies of Small States. Journal of International Relations, 12(1), 89–105.

21. Smith, G. (2015). The Politics of Energy in the Caucasus. London: Routledge.

22. Shaffer, B. (2012). Energy Politics. University of Pennsylvania Press.

23. Zeynallı, R. (2018). "Multivektor xarici siyasət: Azərbaycan nümunəsi". Siyasi Elmlər Məcmuəsi, 7(1), 110–128

24. Üzeyir Əliyev, R. (2019). Zəngəzur dəhlizinin regional əhəmiyyəti və geosiyasi perspektivləri. *Beynəlxalq Əlaqələr Jurnalı*, 12(4), 78–91

25. Freire, M., & Saravia, D. (2020). Energy Geopolitics and the Caspian Region: Challenges and Opportunities. Energy Policy, 137, 111–127. https://doi.org/10.1016/j.enpol.2019.111127

26. Turan, V., & Aydın, H. (2024). "Security Cooperation in the South Caucasus." *International Security Journal*, 15(1), 34–56.

27. EPRS. (2022). The EU's role in the South Caucasus. European Parliamentary Research Service. https://www.europarl.europa.eu

28. UNDP. (2023). Humanitarian demining in Azerbaijan: Recovery and development. https://www.undp.org/azerbaijan

Technical sciences

INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT) AND INFRASTRUCTURE USED IN SMART CITIES

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Abstract

Smart cities are fundamentally built on the integration of people, social capital, and Information and Communication Technology (ICT) infrastructure, aiming to foster sustainable economic development and improve the quality of life. The smart city concept is generally examined through six core components: Smart Economy, Smart Society, Smart Mobility, Smart Governance, Smart Environment, and Smart Living. Cities that incorporate these components and strive toward a future-oriented, resilient, independent, and highly aware citizenry are defined as Smart Cities. With this approach, it is expected that the ICT and digital infrastructure implemented in cities will promote sustainable economic growth and enable more effective management of natural resources through intelligent governance. To achieve a high quality of life and efficient urban management, smart cities must possess spatial intelligence supported by both hardware and software infrastructures. Long-term maintenance of a high standard of living and efficient use of natural resources are only possible in cities equipped with location-aware intelligence.

Keywords: Smart Cities, ICT, IDC, Sentilo platform, Baltimore Open Air project, Qlue My City

Spatial intelligence is a cognitive and conceptual process that involves collecting and processing location-based data, enabling real-time alerts, prediction, machine learning, collective intelligence, and sharing of problem-solving approaches. Geographic Information Systems (GIS) play a crucial role in both establishing the theoretical foundation of the smart city concept and in the practical collection, processing, analysis, and presentation of data. Although GIS significantly enhances urban management, its full potential is still not fully utilized.

Accurate, up-to-date, and comprehensive data are critical in designing, modeling, and planning Smart Cities. Geomatics and GIS hold an important position in the collection and processing of Earth-related data. The infrastructure of spatial information systems required by Smart Cities must be interactive, capable of real-time response, mobile, and possess control and autonomy features. Smart Cities demand the real-time presentation of data in both spatial and temporal dimensions [1,3,5].

Spatial information systems where temporal-spatial geographic information is generated, stored, processed, presented, and accessed in real time are referred to as 4-Dimensional Geographic Information Technologies (4D GIT).

Open Data

Open data is defined as data that can be accessed and used freely by everyone without being subject to any copyright, patent, or other control mechanisms, and without legal, financial, or technical barriers [21]. Essentially, open data refers to data that can be freely accessed, processed, used, modified, and redistributed by third parties.

The fundamental requirements of open data include being free of charge and unrestricted, accessible at any time and from anywhere, enabling global participation, being understandable by humans and readable by machines, and complying with open data standards. Open data is data that can be accessed, used, and shared by everyone without any cost. Real-time traffic data, real-time public transportation schedules, educational data, and various statistical datasets can be given as examples of open data.

Open Government refers to the transparent sharing of data and information owned by government institutions with the public, either directly by the government or by institutions under government control. Open data should be freely accessible online, and these data should be usable and distributable without restrictions [8].

The types of open data that should be shared within the open government framework are as follows:

- Company-related data
- Crime and justice statistics
- Observational data
- Educational data
- Financial and contract data
- Spatial/geographical data
- Global development data
- Accountability and democracy-related data
- Health data
- Science and research data
- Statistical data
- Social mobility and development data
- Transportation and infrastructure data

In Türkiye, there is no "data.gov" portal similar to international examples. However, within the scope of the Official Statistics Program (OSP), efforts are underway to prepare and publish national statistics and datasets in accordance with defined standards. As part of this initiative, the portal resmistatistik.gov.tr has been established. Through this portal, open access is provided to all officially produced statistics.

Although applications related to open data usage in Türkiye are limited, several examples do exist. The Turkish State Meteorological Service archives data such as weather forecasts and climate models produced by the institution. Since the data transmitted by the institution to the Global Telecommunications System are understandable, these datasets are considered within the scope of open data. Additionally, these data are transmitted in GPS code and converted into human-readable formats by systems. Another example is the Şahinbey Municipality of Gaziantep, which has established an Open Data Portal and initiated a test publication with 18 grouped datasets.

The widespread use of open data offers various benefits in terms of improving public services, fostering innovation, increasing economic value, enhancing efficiency, and ensuring transparency. Through the use of open data, public services can be delivered more effectively and the development of new services can be supported. Open data also facilitates collaboration between public institutions and citizens, making public services more measurable and accountable. Furthermore, the use of open data contributes to the development of the private sector [11].

Accessibility of open data is one of the most fundamental components in the development and improvement of smart cities. Today, many countries worldwide and in Europe have recognized the value generated by open data usage and are developing strategies accordingly. Cooperation among government institutions and between different governmental bodies plays a crucial role in the sharing of these data. Particularly in the United States, the United Kingdom, and many European countries, urban planning, infrastructure, tourism, and transportation data are shared with citizens through open data portals.

The importance of sharing real-time data is increasing day by day, and such data are widely used in many mobile applications in daily life. Additionally, local governments can overcome various challenges such as environmental and air pollution, traffic congestion, water quality monitoring, and water leakage by utilizing open data and citizen participation–based data collection methods.

Within the smart city concept, a wide range of data related to the city are collected through smart devices installed in various urban areas. Sharing these collected open data through open data portals enables the private sector, public institutions, and new entrepreneurs to analyze urban problems and develop solutions. This approach requires a data-driven governance mechanism. For example, traffic density can be measured through sensors installed at traffic lights, enabling traffic optimization and contributing to the improvement of citizens' quality of life. Data collected by sensors deployed throughout the city can help reduce crime rates and improve urban planning. The development of smart city applications aimed at solving urban problems is fundamentally based on the use of information and communication technologies (ICT) and open data.

One of the primary objectives of smart cities is to ensure effective urban governance by providing open access to urban data and statistics, together with connected networks and infrastructure. Therefore, one of the most critical steps in the transition to smart cities is ensuring that urban data are accessible to citizens and other stakeholders. The greatest obstacle in the process of sharing data openly is the lack of awareness regarding the benefits of open data usage. When shared openly, data can become a meaningful tool that enhances societal well-being and improves quality of life.

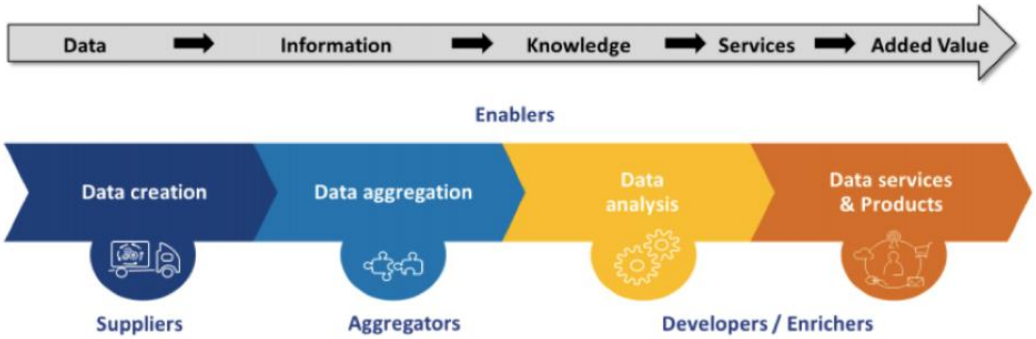

Figure 1. The process of deriving meaningful information from data

Today, numerous successful applications based on open data have been developed to facilitate urban life and enhance quality of life. Some of these applications are described below.

Urban Data Platform: City Data Platform

The Urban Data Platform, developed by the European Commission, is an open data sharing platform that enables comparative analysis and benchmarking. Through this platform, a wide range of data from European Union member states can be visualized and compared at both regional and national levels [2].

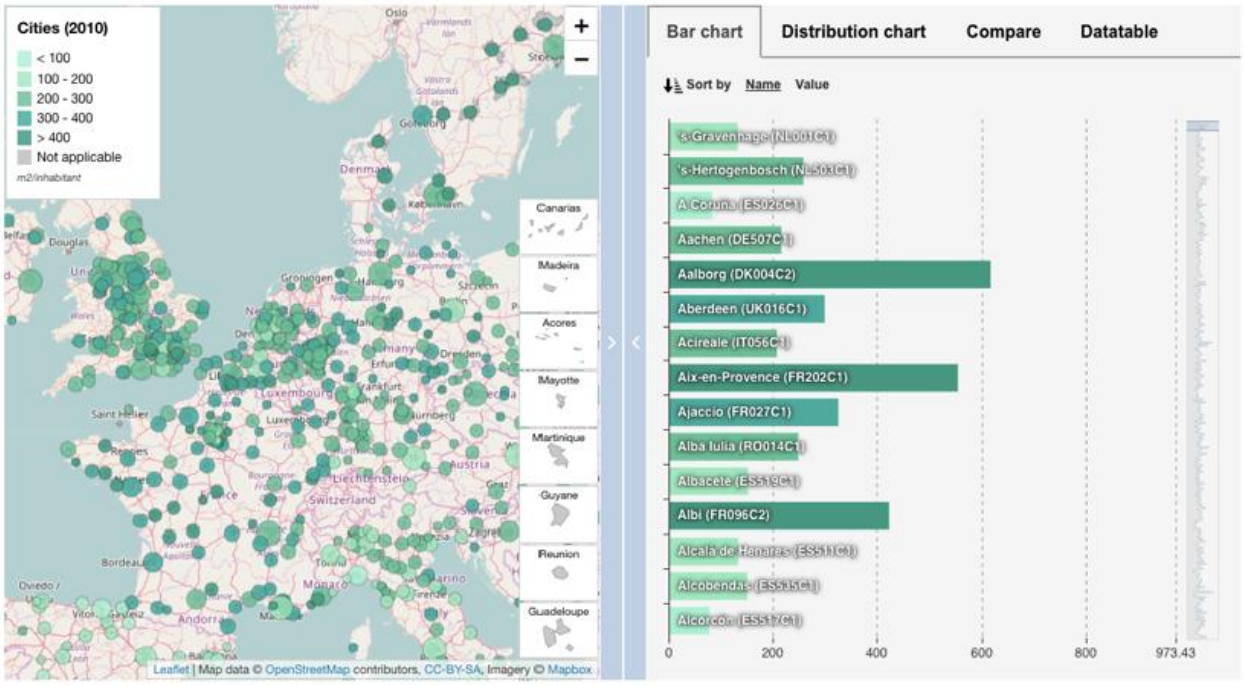

Figure 2. Population density within areas used for residential, industrial, and commercial purposes

Sentilo Platform

One of the major challenges in the transition to smart cities is the use of different databases by different institutions. The existence of heterogeneous databases leads to a lack of integration of urban data, data redundancy, and increased costs associated with ensuring data interoperability for infrastructure investments. This challenge can be addressed by collecting data within a unified global platform and enabling their use by multiple institutions.

Sentilo is a platform in which all sensor data within a city are collected in a single system and made available to various institutions and citizens through an Application Programming Interface (API). In addition, Sentilo is an open-source platform that is continuously improved through contributions from software developers [4].

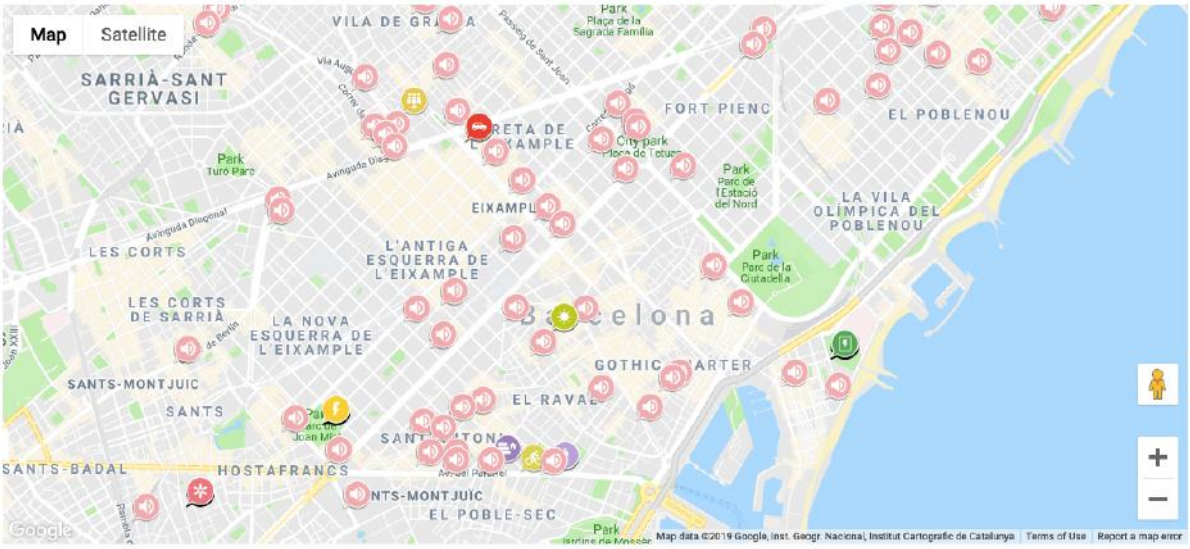

Figure 3. Sentilo Sensor Map

Baltimore Open Air Project

Within the scope of the Baltimore Open Air project, 250 air quality monitoring sensors were installed across the Baltimore region of the city of Maryland. These sensors enable real-time measurements of temperature, humidity, ozone, and nitrogen dioxide in different parts of Baltimore. The collected measurements are shared in real time on the project's official website. As part of the project, climate variables are continuously monitored, and the platform serves as an effective feasibility and analysis tool for initiatives aimed at improving regional air quality.

New York Participatory Budgeting

Through the *Participatory Budgeting* platform, which is New York City's citizen-participation–based budgeting system, residents are able to spatially share their ideas on how a one-million-dollar portion of the municipal budget should be allocated. The submitted proposals are marked on a map and voted on by other citizens, and the project receiving the highest number of votes is subsequently implemented.

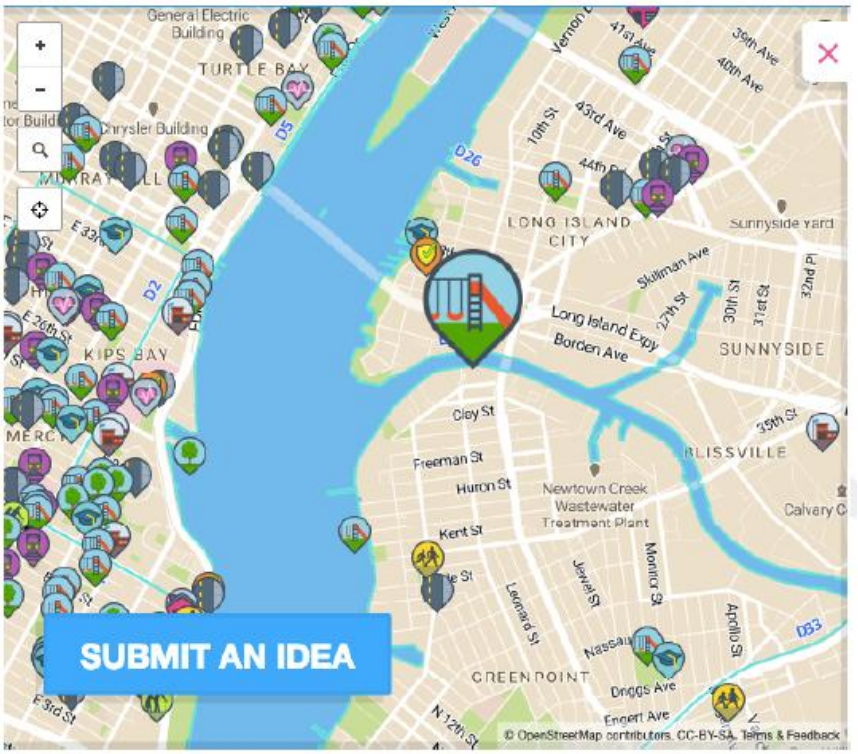

Figure 4. Distribution of New York Participatory Budgeting Projects

Smart Beyoğlu

The Smart Beyoğlu application is a mobile platform that consolidates all municipal services and administrative processes of the Beyoğlu Municipality into a single system. Through the Smart Beyoğlu application, information related to approximately thirty thousand buildings and nineteen thousand businesses in Beyoğlu

is made available to citizens via a barcode-based system. Each business can be inspected using its assigned barcode, and citizens can query detailed information about businesses through the same barcode mechanism.

Additionally, citizens can use the application to access and obtain information on municipal services such as cleaning services, food and beverage facilities, accommodation, and other local services [6,7,20].

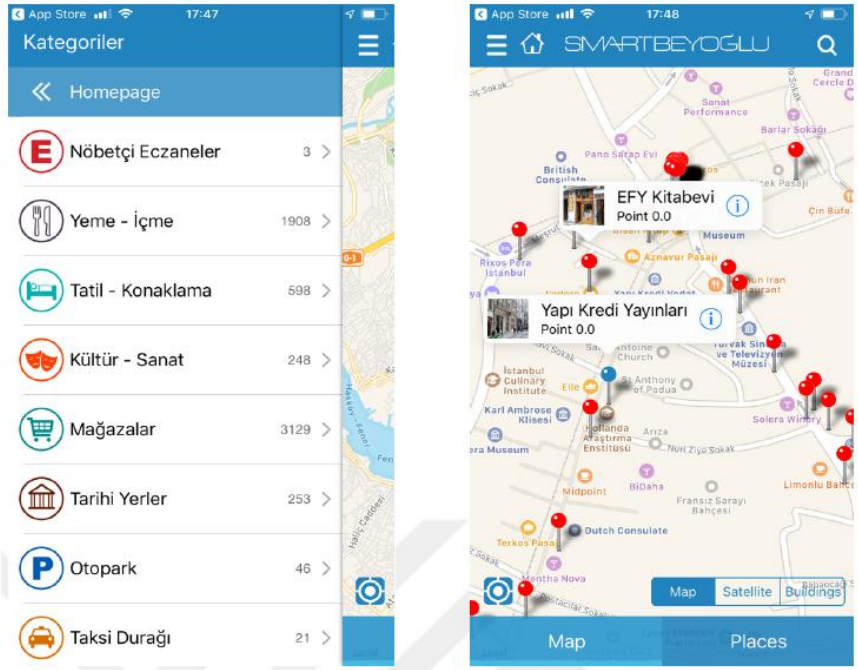

Figure 5. Smart Beyoğlu User Interface

Data.gov (United States of America)

In the United States, approximately 190,000 datasets were made publicly available as open data on the internet in 2009, providing access to the general public and all internet users in need of such information. These datasets have contributed to the development of numerous applications and services.

According to the Open Data Barometer Index, the United States ranks second in terms of open data performance. Approximately 92% of government-held information is shared as open datasets through the **data.gov** platform [4].

Figure 6. Data.gov Dataset Themes

Trafikverket (Sweden)

The Trafikverket platform provides real-time traffic data free of charge to private enterprises and citizens. By utilizing the data offered through this platform, numerous mobile applications have been developed to provide transportation solutions and travel recommendations.

Qlue My City (Indonesia)

Qlue My City is a map-based platform that enables citizens to share their complaints with authorities in real time on a location-based basis. Depending on the location, regional or local government authorities analyze these complaints and implement the necessary improvements accordingly [22].

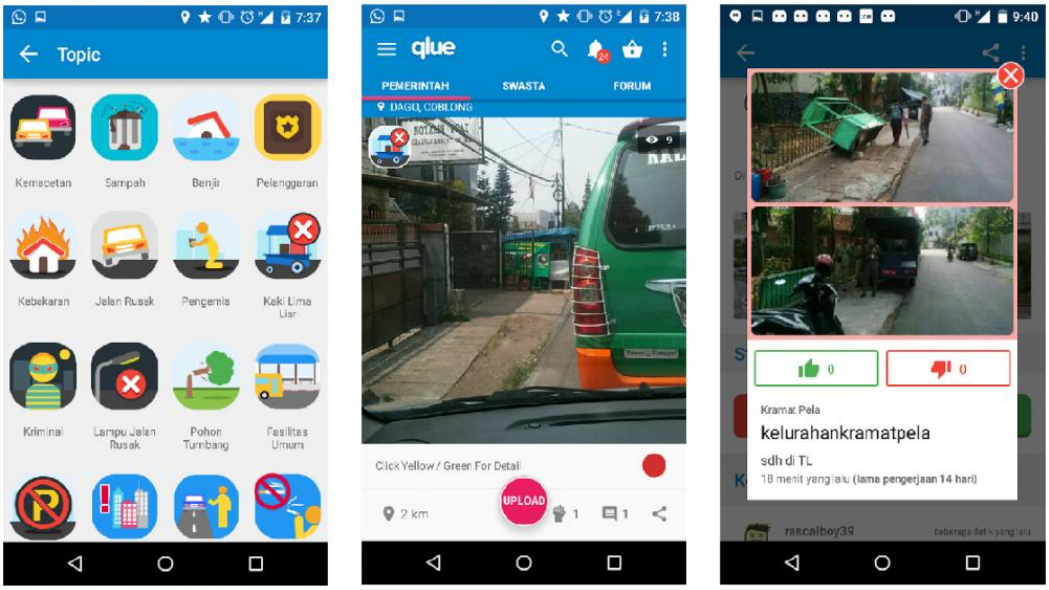

Figure 7. Qlue My City Application Interface

Big Data

Today, data—similar to human and financial resources-has become a critical asset that significantly influences the economy and society. According to IBM estimates, approximately 2.5 quintillion bytes of data are generated every day. Furthermore, nearly 90% of the data currently in existence has been produced within the last two years [19].

This rapidly generated data includes spatial data, statistical data, weather data, transportation data, energy consumption data, health-related data, and social media content. Efforts to extract meaningful insights from these large volumes of data have driven the development of innovative technologies and advanced analytical tools.

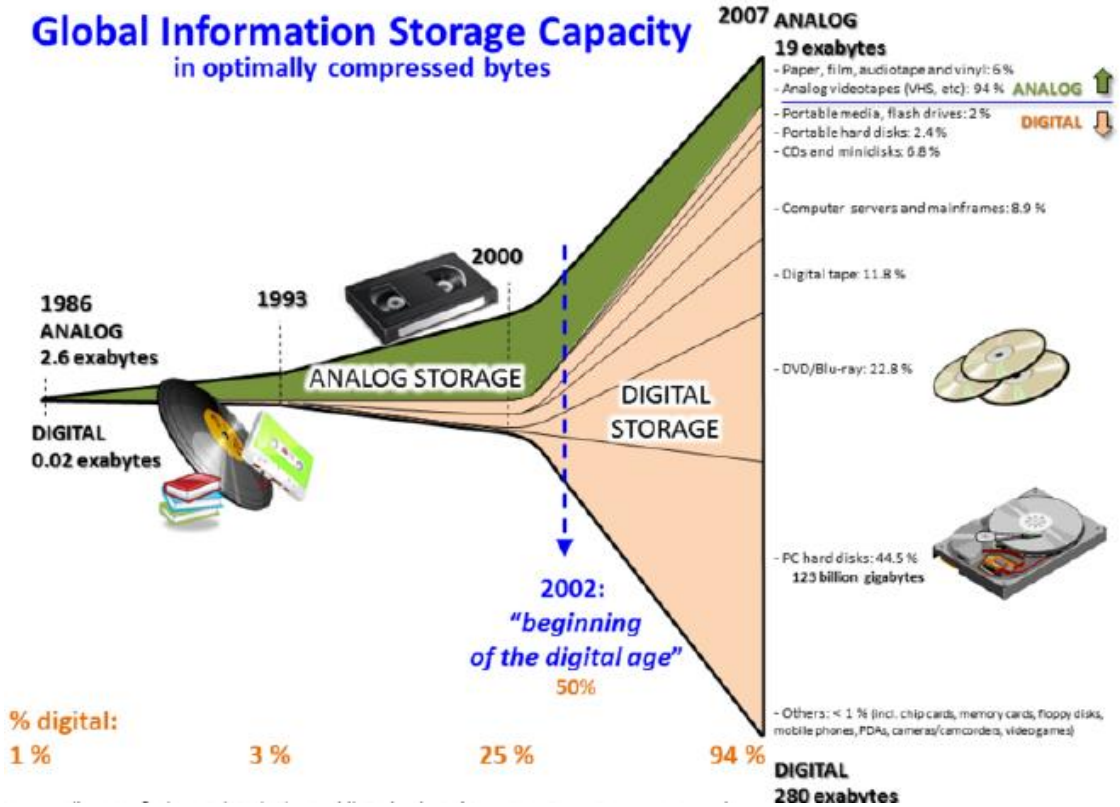

Figure 8. Global Data Storage Capacity

High-volume data generated from multiple sources within a very short period of time are defined as *big data*. Big data can be produced by humans or by devices. Climate data collected by sensors, satellite imagery, photographs, videos, shopping transaction records, and GPS signals are examples of data generated by devices.

The information technology research firm Gartner defines big data as information assets characterized by high volume, high velocity, and/or high variety that require innovative forms of processing to enable enhanced decision-making, process optimization, and knowledge discovery. Similarly, the International Data Corporation (IDC) defines big data as a new-generation technology that derives economic value from high-velocity, high-volume, and highly diverse data streams [10, 14].

The National Institute of Standards and Technology (NIST) emphasizes these three fundamental characteristics of big data and states that large-scale datasets-primarily characterized by volume, velocity, variety, and/or variability-that require scalable architectures for efficient storage, manipulation, and analysis can be classified as big data [12].

Big data is generated across a wide range of sectors, from energy to healthcare. It is anticipated that assigning meaning to big data at each stage of the value creation process will be central to the future economy. The effective use of big data is expected to create numerous opportunities in various fields, including transportation, healthcare, manufacturing, and the energy sector.

Big data can also be explained through its defining characteristics: volume, variety, velocity, and veracity. *Volume* refers to the amount of data generated and stored. Depending on the size of the data and its potential to produce meaningful information or insights, the data may be classified as big data. *Variety* is a critical factor for effective analysis and prediction, as big data often consists of heterogeneous data formats. For instance, a dataset composed of photographs, text, audio, and video can be integrated through data integration techniques and subsequently analyzed. *Velocity* refers to the frequency of data generation, as well as the speed at which data are processed and disseminated. Big data is generally available in real time. *Veracity* refers to data quality and the accuracy of the value derived from the data.

Due to these characteristics, extracting meaningful information from big data using traditional technologies is highly challenging. Therefore, various advanced analytical methods and algorithms have been developed to utilize big data more effectively. One such method is *data mining*, which is a process that employs a wide range of data analysis techniques to reveal patterns and structures within large databases [7]. The process of extracting meaningful information from big data is referred to as data mining.

Data mining consists of a series of sequential processes. These steps are as follows:

1. **Data Cleaning:** Removal of erroneous and inconsistent data.
2. **Data Integration:** Integration of data obtained from different sources.
3. **Data Selection:** Selection of the relevant data subset for analysis.
4. **Data Transformation:** Conversion of data into a suitable format for processing, often through clustering or aggregation.
5. **Data Mining:** Extraction of patterns from large datasets to obtain meaningful information.
6. **Pattern Evaluation:** Assessment and validation of the discovered patterns.
7. **Knowledge Presentation:** Visualization and presentation of the derived meaningful information.

These steps collectively illustrate the process of extracting meaningful information from big data.

Data mining is a comprehensive process that encompasses multiple disciplines, including statistics, machine learning, pattern recognition, database techniques, visualization, algorithms, and high-performance computing. Depending on the type of dataset and the objective of big data analysis, these techniques can be applied as appropriate [8].

These techniques are illustrated in the figure below. However, it is important to note that meaningful information can only be obtained from the data after these techniques have been applied.

Data mining is an effective method within the smart city concept, contributing to the decision-making process by analyzing data obtained from various sources. The application of big data technologies for smart cities enables efficient data storage and processing, thereby generating insights that can support the development of new smart city services [11, 15].

Big data facilitates decision-makers in managing urban resources and planning for the future. The figure below illustrates the process of generating, storing, and processing big data collected from different domains within smart cities.

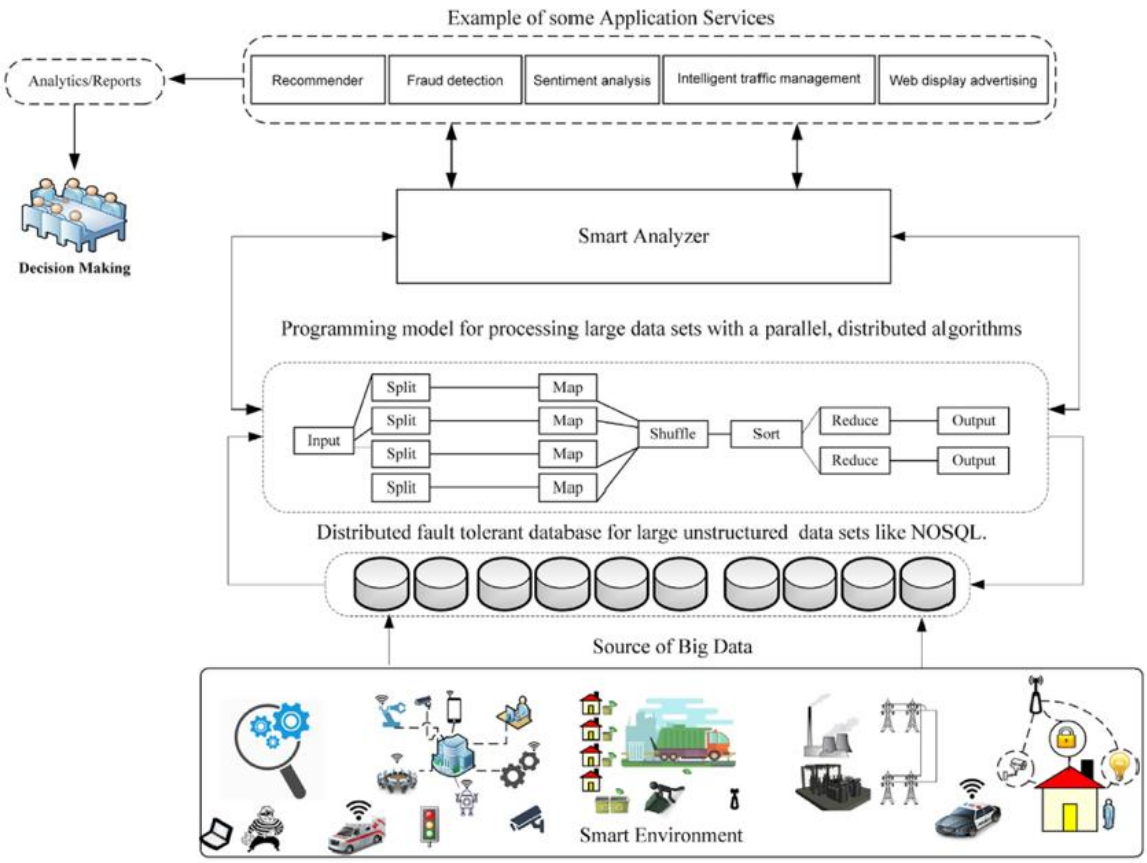

Figure 9. The process of generating, storing, and processing big data collected from various domains in smart cities

One of the fundamental practices that every city must implement on the path to becoming a smart city is the installation of sensors throughout the urban infrastructure, both aboveground and underground, to collect real-time data. The big data obtained from these deployed sensors, when analyzed using advanced analytical methods, facilitates urban monitoring and supports decision-makers in planning and managing the city's future.

Smart cities leverage data mining, the Internet of Things (IoT), and cloud computing technologies to respond in real time to the needs of public services, security, healthcare, and environmental protection, thereby enhancing their overall operational capabilities [16].

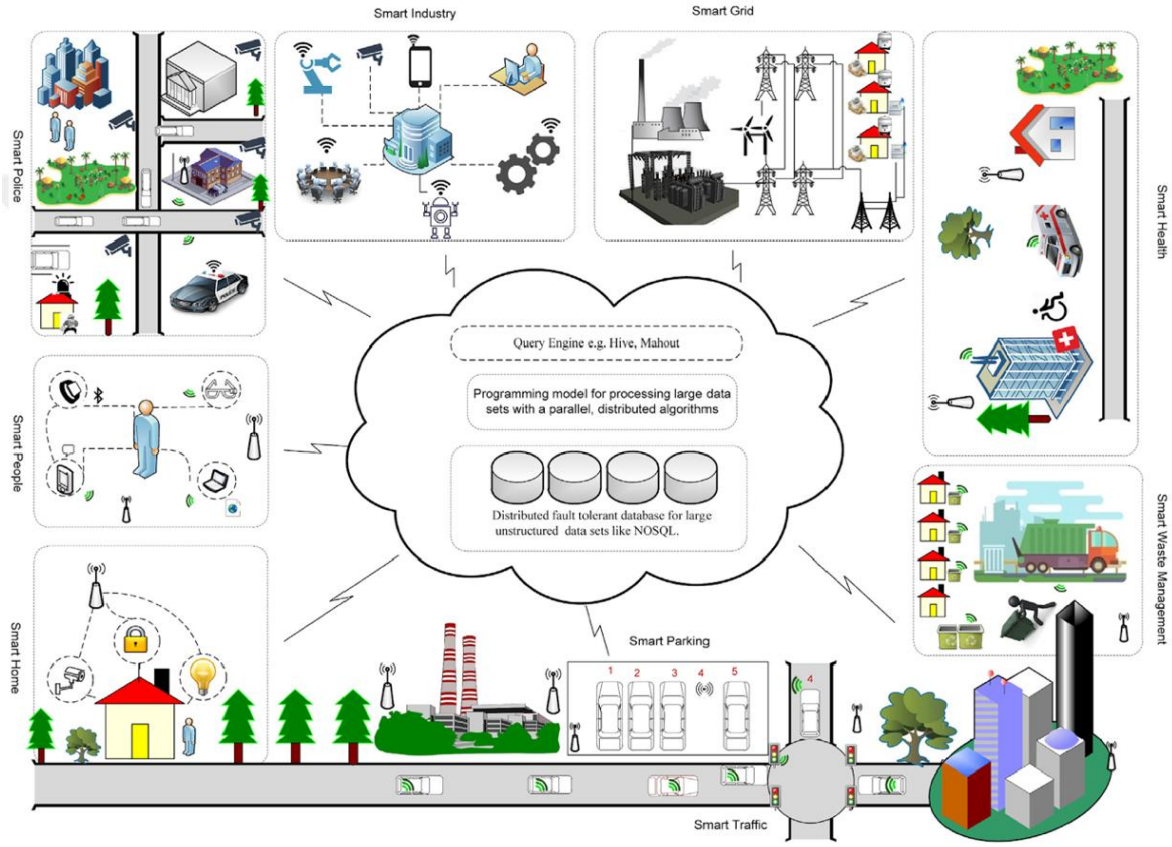

Figure 10. Schematic Representation of Data Collected in Smart Cities

Cloud Computing

According to the definition provided by the National Institute of Standards and Technology (NIST), "Cloud computing is a model that enables ubiquitous, convenient, and on-demand access to a shared pool of configurable computing resources. These resources—such as computer networks, servers, databases, applications, and services—can be provisioned and released with minimal management effort or service provider interaction" [9]. Cloud computing is not a product, but a collective term for a service model.

Cloud computing can be defined as a model through which users access various computing services—including processing, storage, and applications—over the Internet without needing to know where the information is stored, on which servers the applications are running, or how they are technically configured. The term "cloud" is used metaphorically to represent the Internet, which is why this computing model is referred to as cloud computing [13].

The cloud computing model allows for the more efficient utilization of computing capacities through scalable hardware and software, enabling users to deploy information technology applications more rapidly and at lower costs.

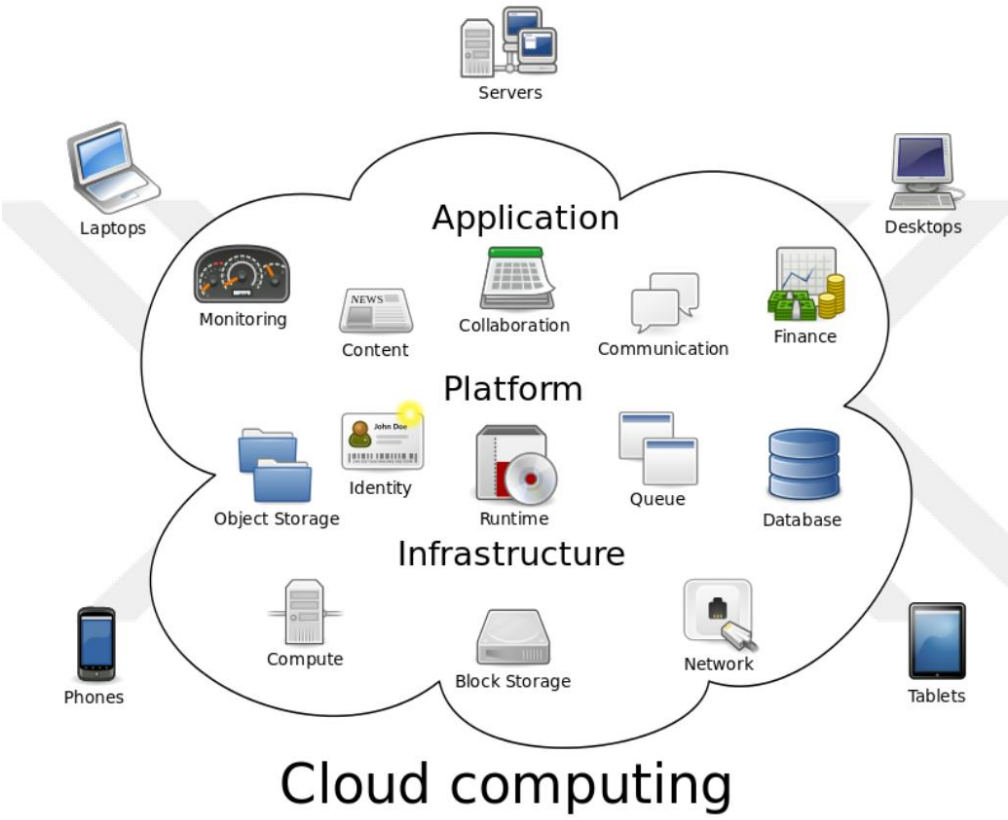

Figure 11. Cloud Computing Model

Cloud computing service delivery consists of three main service models: SaaS, PaaS, and IaaS. These services, along with explanations of their deployment models, are detailed below.

Software as a Service (SaaS): SaaS refers to software applications hosted on a server by a service provider and made available to multiple individuals or organizations. Through this service, organizations can access cloud computing services without incurring licensing or software costs, paying only for their usage. Users are relieved from installation, maintenance, and licensing issues, thereby saving time and costs associated with these tasks. Examples of SaaS include Gmail, Google Docs, and Salesforce.com (CRMaaS).

Platform as a Service (PaaS): PaaS provides customers with a platform to develop and run their own applications, along with complementary services and the necessary technological infrastructure. Users have no control or management capabilities over the components of the platform infrastructure, except for their own applications. Examples of PaaS platforms include Amazon Machine Learning (AML), Microsoft Azure Machine Learning, and Google AI: TensorFlow.

Infrastructure as a Service (IaaS): IaaS allows customers to provision and configure the fundamental computing resources they require (such as processors, storage, and network resources) and install operating systems and applications on top of them. While customers do not manage or control the underlying infrastructure, they have full control at the operating system level and can manage certain network components such as firewalls. Examples of IaaS include **Amazon Elastic Compute Cloud (EC2), Windows Azure**, and **Google Compute Engine**.

Cloud deployment models include:

• **Private Cloud:** A cloud created or leased by a single organization. The infrastructure operates exclusively for that organization and is managed either by the organization itself or by a third party.

• **Community Cloud:** A cloud shared by a specific community. The infrastructure is shared among several organizations or firms that share the same objectives, security requirements, and management style. It can be managed by the organizations, firms, or a third party.

• **Public Cloud:** A cloud infrastructure available to the public or a large industry group. The cloud provider owns and manages the infrastructure and makes resources such as software and storage accessible over the Internet. Examples include **Amazon EC2**, **IBM BlueCloud**, **Sun Cloud**, **Google AppEngine**, and **Windows Azure Service Platform**.

• **Hybrid Cloud:** A composition of two or more cloud models. These clouds are interconnected using standardized or proprietary technologies to allow the transfer of software and data without losing their individual characteristics.

The advancement of cloud computing technology has enabled the storage and accessibility of big data over the Internet. These capabilities have allowed the industrial application of big data, one of the fundamental components of **Industry 4.0**.

Internet of Things and Sensors

Wireless Sensor Network (WSN) technology has enabled **ubiquitous sensing**, allowing objects to perceive their environment simultaneously across various domains of daily life. This technological advancement facilitates the measurement of ecological indicators, natural resources, and urban environmental parameters in real time, enabling the extraction of meaningful insights and improving environmental analysis.

The widespread communication between objects within a network, and the subsequent triggering of actions based on these interactions, has led to the emergence of the Internet of Things (IoT) concept. Equipped with sensors and actuators, connected objects share information to develop a common operating picture (COP). With the recent advancements in technologies such as RFID tags, embedded sensors, and actuators, IoT has evolved from its initial phase to become a technology poised to transform the present Internet into the Future Internet [16, 18].

According to the International Data Corporation (IDC), there are currently approximately 9 billion connected devices, and this number is projected to reach 212 billion by the end of 2020. The Global System for Mobile Communications (GSMA) estimates that these connected devices will contribute approximately USD 1.3 trillion to the global economy, particularly in the health, automotive, and electronics sectors. In simple terms, the Internet of Things can be defined as a concept in which machines and everyday objects are connected through the Internet. Typically, IoT devices are monitored and controlled remotely via wireless network technologies.

Atzori [16] classifies IoT into three main dimensions: Internet (middleware), object (sensor), and semantic (knowledge). Such classification reflects the inherently interdisciplinary nature of IoT and helps highlight the benefits provided across various application domains. According to the RFID Group, IoT refers to the interconnection of uniquely addressable objects through Internet communication protocols.

The European Research Group on IoT defines IoT as a platform in which objects actively participate in business, informational, and social processes. Objects autonomously react to events in their physical environment, triggering actions or services without direct human intervention. According to Forrester, IoT enables the integration and efficient utilization of IT technologies to manage infrastructure, administration, education, healthcare, security, real estate, transportation, and other services interactively and consciously. Gubbi emphasizes that IoT encompasses innovative applications that connect perceivable and actuable objects, enable information sharing among devices, and facilitate the development of a common operating picture. These applications can be successfully implemented in environments where objects have seamless connectivity and access to cloud computing infrastructure.

The IoT concept relies on three main components that enable ubiquitous computing:

Hardware: Sensors, actuators, and embedded communication devices form the hardware layer of IoT technology.

- **Middleware:** Comprises the necessary storage and software for data analysis, configured according to specific needs.
- **Presentation:** Includes user interfaces and analytical tools that are easily interpretable and accessible across multiple platforms.

Key enabling technologies for IoT include Radio Frequency Identification (RFID), Wireless Sensor Networks (WSNs), Secure Data Aggregation, Addressing Schemes, data storage, and data visualization.

According to Gartner's IT Hype Cycle, IoT is considered an emerging technology. The cycle illustrates IoT's introduction, industry adoption, development, and deployment across different applications. It is expected that IoT technology will reach broader market adoption within the next 2–5 years.

Over the past decade, trends in Google searches for terms such as Internet of Things, Wireless Sensor Networks, and Ubiquitous Computing demonstrate consistent growth, reflecting increasing interest and awareness in these technologies.

Figure 12. Data Flow in IoT Technology Provided by End Users and Applications

In smart cities, IoT technology is extensively applied in various domains, including **Smart Parking, Smart Healthcare, Smart Water Management, Smart Solid Waste Management, Smart Transportation, and Smart Energy.** The figure below illustrates the use of IoT technology in smart city applications [18].

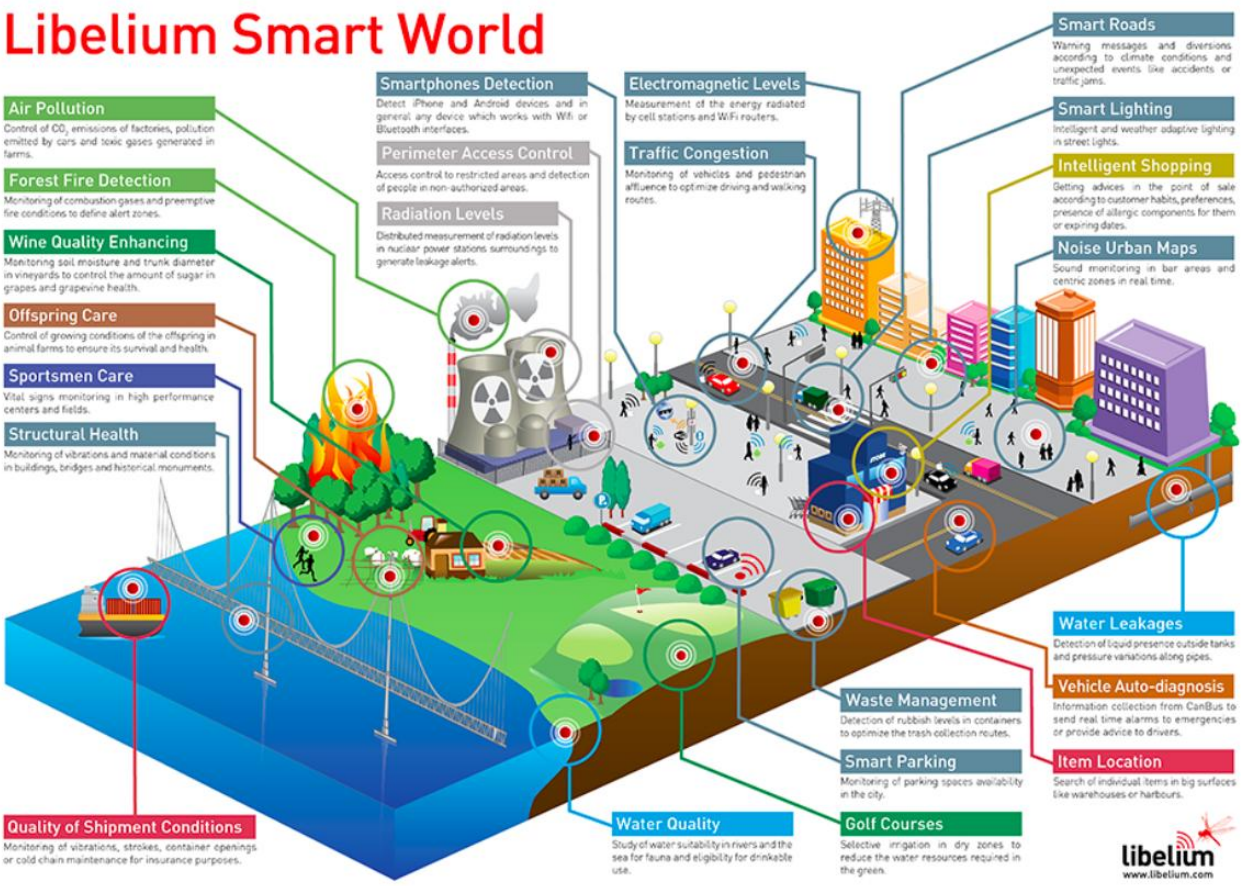

Figure 13. Visualization of IoT Applications in Smart Cities

Conclusion. To establish a **Smart City Spatial Information System (SIS) infrastructure framework**, authorities responsible for mapping and production must regularly update **static spatial data**, including maps, and transfer them into the database at defined intervals. Real-time spatial data generated by the **Internet of Things (IoT)** devices and other smart sensors should be transmitted to **big data centers** via wired or wireless internet connections.

The integration of open data, big data, cloud computing, IoT, and GIS has become essential for the development of smart cities. Open data ensures transparency and citizen engagement, while big data and data mining enable the extraction of meaningful insights from vast volumes of real-time and static urban data.

Cloud computing provides scalable infrastructure for data storage and processing, supporting efficient, cost-effective, and collaborative urban services. IoT and sensor networks enable continuous monitoring of urban environments, generating real-time spatial and temporal data that, when combined with GIS, form a 4D spatial information framework for informed decision-making.

Together, these technologies allow cities to operate in a data-driven, responsive, and sustainable manner, improving public services, optimizing resources, fostering innovation, and enhancing the quality of life for citizens. The effective integration of these systems lays the foundation for future-ready smart city ecosystems.

Literature

1. **Adrian Smith,** (2018). Smart cities need thick data not big data 2018
2. **Caragliu, A., Del Bo, C., & Nijkamp, P.** (2011). Smart cities in Europe. Journal of Urban Technology, 18(2), 65–82. Routledge.
3. **Daniel S and DoranM-A** (2013) GeoSmartCity: Geomatics contribution to the Smart City, 2013. In: Proceedings of the 14th Annual International Conference on Digital Government Research, 17–20 June, Quebec City, 65–71.
4. **Dameri, R. P.** (2013). Searching for smart city definition: a comprehensive proposal. International Journal of Computers & Technology, 11(5), 2544–2551(Council for Innovative Research).
5. **Deren LI,** (2013) Geomatics for Smart Cities - Concept, Key Techniques, and Applications, Geospatial Information.
6. **Ebem Ş**, (2013), Kamu Bilişim Sistemleri Açısından Bulut Bilişimin Teknik, Yönetim ve Hukuki Boyutlarıyla İncelenmesi: Bilgi Teknolojileri ve İletişim Kurumu İçin Öneriler, Bilgi Teknolojileri ve İletişim Kurumu Uzmanlık Tezi, Ankara

7. **Oğuzlar A**.,(2004) Veri Madenciliğine Giriş, Ekin Kitapevi, 2004.
8. **Han J., Pei J., and Kamber M.,** (2012) Data mining: concepts and techniques. Elsevier Inc., 2012
9. **Marston, S., Li, Z., Bandyopadhyay, S., Zhang, J., & Ghalsasi, A**. (2011). Cloud computing -- The business perspective. Decision Support Systems, 51(1), 176-189.
10. **Mell, P. ve Grance, T.**, (2011). The NIST Definition of Cloud Computing, NIST Special Publication 800-145, September 2011.
11. **Novruzova Z. A., Jabiyeva T.E.** (2026) Designing the framework of a Smart City spatial information system infrastructure. XXII International Scientific and Practical Conference «Modern science: theoretical and practical view», January 20-21, 2026, Madrid. Spain. 111 p. ISBN 978-91-65424-56-2.
12. **NIST**(2015) Big Data Public Working Group, Big data interoperability framework: Definitions, National Institute of Standards and Technology (NIST), 2015
13. **Sultan, N. A.** (2010). Reaching for the "cloud": How SMEs can manage. International Journal of Information Management
14. **Gantz J., Reinsel D**.,(2011) “Extracting value from chaos”, IDC iview (1142), 2011
15. **Gong, J. Y., and G. L. Wang**. (2013). “From Digital City to the Smart City: New Challenges to Geography Information Technology.” Journal of Geomatics 38 (2): 1–6. Doi: http://dx.doi.org/10.14188/j.2095-6045.2013.02.001
16. **Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M.** (2013). Internet of Things (IoT):a vision, architectural elements, and future directions. Future Generation Computer Systems, 29(7), 1645–1660.
17. **L. Atzori, A. Iera, G. Morabito**,(2010) The Internet of Things: a survey, Computer Networks 54 (2010) 2787–2805
18. **Zhenjiang, Jiangsu** (2013)- The framework of smart city based on cloud computing Liu Chaohua* School of Management, Jiangsu University
19. **Wessler M.(**2013) Big Data Analytics For Dummies, Published by John Wiley & Sons, Inc., Hoboken, New Jersey, 2013
20. **Url-1** <http://www.smartbeyoglu.com/>,date retrieved 01.02.2019
21. **Url-2** <http://www.opendatabarometer/>,date retrieved 01.02.2019
22. **Url-3** <https://qlue.co.id/solutions/?lang=en />,date retrieved 01.02.2019

PEDAGOGICAL OPPORTUNITIES OF USING ARTIFICIAL INTELLIGENCE TOOLS IN TEACHING THE TOPIC "COMPUTER NETWORKS"

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«КОМПЬЮТЕРЛІК ЖЕЛІЛЕР» ТАҚЫРЫБЫН МЕҢГЕРТУДЕ ЖАСАНДЫ ИНТЕЛЛЕКТ ҚҰРАЛДАРЫН ПАЙДАЛАНУДЫҢ ПЕДАГОГИКАЛЫҚ МҮМКІНДІКТЕРІ

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Abstract

This article provides a comprehensive analysis of the pedagogical potential of using artificial intelligence (AI) technologies to modernize the teaching of the "Computer Networks" section in the school informatics curriculum. The study identifies the difficulties that students most often encounter when mastering networking concepts (understanding multi-layer models, learning the principles of routing and addressing, and linking the operation of protocols with practical activities) and examines effective ways to overcome these challenges. The authors aim to demonstrate, through concrete methodological examples, how the integration of AI tools into the learning process can personalize learning outcomes, enhance the visual representation of learning content, and strengthen its practical orientation. In addition, the article substantiates the role of AI technologies in improving learning effectiveness through adaptive learning, virtual laboratories, interactive simulations, and automated feedback systems. The proposed conclusions are empirically validated by a lesson scenario on the topic "Principles of Network Protocol Operation Based on the OSI and TCP/IP Models" for grades 10–11.

Аннотация

Бұл мақала мектептегі информатика пәнінің «Компьютерлік желілер» бөлімін оқыту үдерісін жаңғыртуда жасанды интеллект (ЖИ) технологияларын қолданудың педагогикалық әлеуетін кешенді түрде талдауға арналған. Зерттеуде оқушылардың желілік ұғымдарды меңгеру барысында жиі кездесетін қиындықтары (көпдеңгейлі модельдерді түсіну, маршрутизация мен адрестеудің қағидаларын игеру, протоколдардың жұмысын тәжірибемен байланыстыру) анықталып, оларды

еңсерудің тиімді жолдары қарастырылады. Авторлар ЖИ құралдарын оқу процесіне кіріктіру арқылы білім алушылардың оқу жетістіктерін дербестендіру, оқу материалының көрнекілігін арттыру және тәжірибелік бағыттылығын күшейту мүмкіндіктерін нақты әдістемелік мысалдар негізінде көрсетуге ұмтылады. Сонымен қатар мақалада ЖИ технологияларының бейімделмелі оқыту, виртуалды зертханалар, интерактивті симуляциялар және автоматтандырылған кері байланыс беру жүйелері арқылы оқытудың нәтижелілігін арттырудағы рөлі негізделеді. Ұсынылған тұжырымдар 10–11 сыныптарға арналған «OSI және TCP/IP модельдері негізіндегі желілік протоколдардың жұмыс қағидалары» тақырыбы бойынша сабақ сценарийі арқылы тәжірибелік тұрғыдан дәлелденеді.

Keywords: artificial intelligence, computer networks, informatics education, OSI model, personalized learning, adaptive technologies, virtual laboratories, cybersecurity, project-based learning, interactive simulations, digital competencies.

Түйінді сөздер: жасанды интеллект, компьютерлік желілер, информатика оқыту, OSI моделі, жекелендірілген оқыту, бейімделмелі технологиялар, виртуалды зертханалар, киберқауіпсіздік, жобалық жұмыс, интерактивті симуляциялар, цифрлық құзыреттер.

Қазіргі білім беру кеңістігі қоғам өмірінің барлық саласын қамтыған цифрландырудың әсерімен түбегейлі өзгеру кезеңін өткеріп жатыр. Бұрынғы «мұғалім – оқулық – оқушы» үлгісі бүгінгі күні күткендей нәтиже бермейді. Себебі қазіргі оқушылар – «цифрлық ортада туған ұрпақ»: олар ақпаратты басқаша қабылдайды, сабақтан интерактивтілік, жедел кері байланыс және алған білімінің күнделікті өмірде қолданылуын күтеді. Осы жағдайда мектептің басты міндеті тек білім берумен шектелмей, оқушыда икемді дағдыларды қалыптастыруға бағытталуы тиіс: сыни ойлау, күрделі мәселелерді шешу, өздігінен білім алу қабілеті. Бұл талап әсіресе жаратылыстану-ғылыми және техникалық пәндерді оқытуда, соның ішінде информатикада айрықша өзекті.

Мектеп информатика курсында оқушыларға ең қиын қабылданатын бөлімдердің бірі – «Компьютерлік желілер». OSI мен TCP/IP сияқты көпдеңгейлі модельдер, бағыттау (маршрутизация), адрестеу, желілік протоколдардың жұмыс істеу қағидалары көбіне оқулықтағы құрғақ сызба деңгейінде қалып қояды. Көрнекі түсіндірудің жеткіліксіздігі және деректердің берілу процесін «қолмен байқап көру» мүмкіндігінің болмауы материалды үстірт меңгеруге, теорияны өмірлік цифрлық тәжірибемен байланыстыра алмауға және соның салдарынан қызығушылықтың төмендеуіне әкеледі. Ал мұғалім уақыт пен ресурстың шектеулілігіне байланысты әр оқушыға жеке тәсіл қолдануға әрдайым мүмкіндік таба бермейді. Өйткені әр баланың оқу қарқыны мен түсіну деңгейі әртүрлі.

Осындай жағдайда жасанды интеллект мүмкіндіктері жай ғана құрал емес, оқытудағы жаңа сапалық өзгеріске бастайтын қозғаушы күшке айналады. ЖИ бұрынғыдай абстракт ұғым болып қалмай, нақты нәтиже беретін практикалық шешім ретінде көрініс табуда. ЖИ-дің әлеуеті күнделікті қайталанатын жұмысты автоматтандыруға (мысалы, тапсырмаларды тексеру), виртуалды көмекші ретінде шексіз шыдамдылықпен түсіндіруге және қолдауға, күрделі жүйелер мен процестерді қауіпсіз виртуалды ортада модельдеуге, сондай-ақ оқу үлгерімі туралы деректерді талдап, әр оқушыға жеке оқу траекториясын құруға мүмкіндік береді.

Сондықтан қазіргі таңда техникалық тұрғыдан күрделі пәндерді оқыту әдістемесін жаңа буынның сұранысына және цифрлық сауаттылық талаптарына сай келетін құралдар арқылы жаңарту қажеттілігі айқын сезілуде.

Бұл мақаланың мақсаты – аталған мәселені жүйелі түрде талдай отырып, жасанды интеллект технологияларының нақты мүмкіндіктерін көрсету. Яғни біз ЖИ-ді қолданудың бағыттарын тек теориялық тұрғыдан түсіндіріп қана қоймай, 10–11 сыныптарға арналған «Желілік протоколдардың жұмыс негіздері: OSI және TCP/IP модельдері» тақырыбында егжей-тегжейлі дайындалған сабақ сценарийін ұсынамыз. Бұл сабақта чат-боттар, бейімделмелі платформалар, виртуалды зертханалар және симуляторлар секілді ЖИ құралдары бір сабақтың ішінде жүйелі түрде қолданылып, күрделі тақырыпты қызықты зерттеу форматына айналдыруға болатыны көрсетіледі. Ең бастысы – ЖИ мұғалімнің орнын басатын дүние емес, керісінше оның серіктесі. Ол мұғалімнің уақытын босатып, шығармашылыққа, бағыттауға және оқушымен терең адами қарым-қатынас орнатуға мүмкіндік береді.

1. ЖИ көмегімен жекелендірілген оқыту

Дәстүрлі білім берудегі негізгі қиындықтардың бірі – әр оқушының жеке ерекшелігін толық ескеру мүмкін еместігі. Себебі бір сыныптағы білім алушылардың оқу қарқыны, танымдық қызығушылығы, дайындық деңгейі және ақпаратты қабылдау тәсілі әртүрлі болады. Мұндай жағдайда мұғалімнің бір мезетте барлық оқушыға бірдей тиімді әдістемелік қолдау көрсетуі күрделене түседі. Нәтижесінде оқу процесі көбіне «орташа деңгейге» бағытталып, бір оқушы үшін тапсырмалар тым

жеңіл, ал екінші оқушы үшін шамадан тыс күрделі болып қалуы мүмкін. Бұл өз кезегінде мотивацияның төмендеуіне, білімдегі олқылықтардың жиналуына және тақырыпты формалды меңгеруге әкеледі.

Осы тұрғыдан алғанда, жасанды интеллект (ЖИ) технологиялары оқытуды жекелендіруге мүмкіндік беретін маңызды құрал ретінде қарастырылады. ЖИ жүйелері оқушының оқу әрекетіндегі мәліметтерді талдай отырып (дұрыс және қате жауаптардың құрылымы, тапсырманы орындау уақыты, қай бөлімде жиі қиналатыны, оқу нәтижесінің динамикасы), әр білім алушы үшін бейімделген оқу траекториясын ұсына алады. Бұл тәсіл оқу материалын оқушының дайындық деңгейіне сәйкестендіріп қана қоймай, оның жеке оқу қажеттілігі мен мүмкіндігін ескеріп, оқу мақсатына біртіндеп жетуіне жағдай жасайды.

ЖИ көмегімен жекелендірілген оқыту әсіресе «Компьютерлік желілер» секілді күрделі тақырыптарды меңгертуде тиімді нәтиже береді. Өйткені OSI және TCP/IP модельдері, маршрутизация, IP-адрестеу, протоколдардың өзара әрекеттесуі сияқты ұғымдар көп жағдайда абстракт сипатта қабылданады және оқушылардан логикалық талдауды талап етеді. ЖИ бұл қиындықты төмендетіп, оқу мазмұнын кезең-кезеңімен, жүйелі түрде ұсынуға мүмкіндік береді.

Мысалдар:

- **Бейімделмелі тесттер:** ЖИ оқушының алдыңғы жауаптарына сүйене отырып тапсырмалардың күрделілік деңгейін автоматты түрде реттеп отырады. Мысалы, егер оқушы OSI моделінің қабаттарын дұрыс ажыратып, олардың қызметін сенімді түсіндіре алса, жүйе келесі қадамда TCP/IP протоколдары, деректерді тасымалдау логикасы немесе нақты жағдайлық тапсырмалар сияқты тереңдетілген сұрақтарды ұсынады. Ал егер оқушы қателессе, ЖИ оған жеңілдетілген тапсырмалармен қайта бекіту мүмкіндігін береді және дұрыс жауапқа алып келетін қысқа түсіндірмелер ұсынады.
- **Чат-боттар мен виртуалды ассистенттер:** Оқушылар кез келген уақытта сұрақ қойып, жедел әрі толық жауап ала алады. Мұндай көмекшілер тек анықтама берумен шектелмей, мысал келтіру, ұқсастық арқылы түсіндіру, қысқа схема ұсыну, қосымша материалға бағыттау сияқты оқуға қолдау көрсету функциясын атқарады. Бұл әсіресе маршрутизация, адрестеу, желі топологиялары, протоколдардың айырмашылығы сияқты күрделі мәселелерді меңгеруде маңызды, себебі оқушы өзіне түсініксіз тұсты қайта сұрауға мүмкіндік алады және білімдегі олқылықты бірден толықтыра алады.

2. Интерактивті симуляциялар мен көрнекілендіру

Компьютерлік желілер теориясы көп оқушыға абстракт болып көрінеді, себебі желідегі ақпарат алмасу процестері көзге көрінбейтін деңгейде жүреді және оны қарапайым түсіндіру арқылы толық меңгерту әрдайым мүмкін бола бермейді. Әсіресе OSI және TCP/IP модельдерінің қабаттары, деректер пакеттерінің құрылымы, протоколдардың өзара байланысы, маршрутизация мен коммутация ұғымдары оқушыға «теориялық схема» күйінде қалып, тәжірибелік мағынасын түсінуге кедергі жасайды. Мұндай жағдайда оқушылардың тақырыпқа қызығушылығы төмендеп, материалды механикалық түрде жаттауға бейімделуі ықтимал.

Осы кедергіні еңсеруде жасанды интеллект (ЖИ) технологиялары маңызды дидактикалық мүмкіндік береді. ЖИ негізіндегі интерактивті симуляциялар мен визуализация құралдары күрделі желілік процестерді нақты әрекет арқылы көрсетуге, желідегі құбылыстарды модельдеуге және оқушының түсіну деңгейін арттыруға ықпал етеді. Мұндай әдіс оқытуды теориядан тәжірибеге көшіреді: оқушы желінің қалай жұмыс істейтінін тек оқып қана қоймай, оны виртуалды ортада құрастырып, бақылай алады.

Интерактивті симуляциялардың артықшылығы – қауіпсіз әрі қолжетімді ортада тәжірибе жүргізуге мүмкіндік беруі. Яғни оқушы нақты желілік құрылғыларды қолданбай-ақ, маршрутизатор, коммутатор параметрлерін баптап, желілік қателердің себебін талдай алады. Сонымен қатар ЖИ бұл процесте оқушының әрекетін бақылап, оның қандай қадамда қателескенін анықтап, түзетуге бағытталған ұсыныстар береді. Осылайша оқу үдерісі тек демонстрацияға емес, әрекетке негізделген зерттеу форматына көшеді.

Мысалдар:

- **Виртуалды зертханалар.** Оқушылар желіні «құрастырып», маршрутизаторды баптап, деректер пакеттерінің бір құрылғыдан екіншісіне қалай өтетінін бақылау мүмкіндігіне ие болады. Мысалы, белгілі бір топологияны орнатып, IP-адрес беру, бағыттау кестесін құру, байланыс қателерін табу және түзету сияқты тапсырмалар орындалады. Сонымен бірге виртуалды зертхана пакеттердің қозғалысын кезең-кезеңімен көрсетіп, желіде ақау немесе кибершабуыл болған жағдайда оның салдарын көрнекі түрде танытады. Мұндай тәжірибе оқушылардың желілік ұғымдарды нақты түсінуіне, логикалық талдау дағдысын дамытуына және практикалық құзыреттілігін қалыптастыруға мүмкіндік береді.

• **Анимациялар және үш өлшемді модельдер.** ЖИ негізіндегі графикалық генераторлар күрделі процестерді визуалды түрде түсіндіруге көмектеседі. Мәселен, DNS жүйесінің домен атауын IP-адреске қалай түрлендіретінін, HTTP протоколы арқылы сұраныс пен жауап қалай берілетінін немесе OSI қабаттарының әрқайсысы ақпаратты өңдеу кезінде қандай қызмет атқаратынын анимациялық модель арқылы көрсетуге болады. Үш өлшемді визуализация оқушыға «дерек қайда жүреді, қалай өңделеді, қандай өзгерістерге ұшырайды» деген сұрақтарға нақты жауап береді. Бұл әдіс желілік архитектураны тек сөзбен емес, көріп қабылдауға мүмкіндік жасап, материалдың есте сақталуын және түсінілуін айтарлықтай жеңілдетеді.

3. Білімді тексеруді автоматтандыру

Оқу нәтижесін бағалау – білім беру үдерісінің ажырамас бөлігі. Дегенмен дәстүрлі мектеп тәжірибесінде бағалау көбіне уақытты көп талап ететін, бірсарынды және қайталанатын жұмыстармен байланысты: тест тексеру, жазбаша жауаптарды бағалау, практикалық тапсырмалар бойынша есептерді қарап шығу, кері байланыс жазу және үлгерімді тіркеу. Мұндай жағдайда мұғалімнің негізгі уақыты оқу мазмұнын тереңдетуге, оқушыны ынталандыруға және шығармашылық тапсырмалар ұйымдастыруға емес, бақылау-бағалау жұмысына жұмсалып кетеді.

Осы тұрғыдан алғанда, жасанды интеллект (ЖИ) білімді тексеру мен бағалау процесін едәуір жеңілдетіп, мұғалімді күнделікті рутиналық міндеттерден босататын тиімді құрал ретінде қарастырылады. ЖИ жүйелері бағалауды автоматтандыру арқылы тек уақытты үнемдеп қана қоймай, кері байланысты жедел ұсынуға, бағалаудың объективтілігін арттыруға және әр оқушыға жеке қолдау көрсетуге мүмкіндік береді. Әсіресе «Компьютерлік желілер» секілді техникалық және логикалық құрылымы күрделі тақырыптарды меңгеруді бағалауда мұндай технологиялардың маңызы жоғары. Себебі желі бойынша тапсырмалар тек дайын жауапты таңдау емес, процесті түсіндіруді, себеп-салдарлық байланыс орнатуды және практикалық әрекет арқылы дәлелдеуді талап етеді.

Мысалдар:

• **Тест пен тапсырмаларды автоматты тексеру.** ЖИ оқушылардың жауаптарын талдап, жиі кездесетін қателерді анықтайды және әр білім алушыға жеке кері байланыс береді. Мысалы, егер оқушы маршрутизация процесін дұрыс сипаттай алмаса немесе OSI қабаттарының қызметін шатастырса, жүйе нақты қай тұста қате кеткенін көрсетіп, қысқаша түсіндірме мен қосымша материал ұсынады. Бұл тәсіл оқушының қателігін «жай ғана белгілеумен» шектелмей, оны түзетуге бағытталған оқыту элементіне айналдырады. Сонымен қатар автоматтандырылған бағалау оқушының біліміндегі әлсіз тұстарын ерте анықтап, түзету жұмыстарын уақытында ұйымдастыруға мүмкіндік береді.

• **Практикалық жұмыстарды талдау.** Компьютерлік желілерді оқытуда практикалық тапсырмалардың үлесі жоғары болғандықтан, оларды бағалау да күрделі процесс болып табылады. ЖИ желі конфигурациясын баптау бойынша есептерді, командалар нәтижесін, желілік құрылғылардың параметрлерін, сондай-ақ желілік трафик логтарын (мысалы, пакеттердің жүру бағыты, кідіріс, қате жіберу жағдайлары) талдап, қателерді табуға көмектеседі. Бұдан бөлек, жүйе оқушыға нақты түзету жолдарын ұсынып, тиімді баптау нұсқаларын түсіндіре алады. Мұндай талдау оқушылардың тәжірибелік дағдысын дамытуға, «неліктен байланыс орнамады?» сияқты мәселелерді өз бетінше шешуге үйретеді және олардың желілік ойлау қабілетін қалыптастырады.

Нақты сабақ үлгісі: «Желілік протоколдардың жұмыс негіздері: OSI және TCP/IP»

«Компьютерлік желілер» бөлімін меңгертуде білім алушылардың теориялық түсінігін практикалық әрекетпен ұштастыру маңызды. Осы мақсатта жасанды интеллект құралдарын қолдану сабақ құрылымын интерактивті, зерттеушілік және тәжірибеге бағытталған форматта ұйымдастыруға мүмкіндік береді. Төменде 10–11 сыныптарға арналған сабақтың үлгілік сценарийі ұсынылады.

Сабақ мақсаттары:

– Желілік протоколдардың қызметін және OSI моделінің құрылымдық-логикалық қағидаларын түсіну;

– Желідегі деректердің берілу үдерісін қабаттар бойынша талдай алу және ақпарат алмасудың кезеңдерін сипаттау;

– Жасанды интеллект құралдарын қолдана отырып, теориялық білімді практикалық тапсырмалар арқылы бекіту және қолдану.

Сабақ жоспары:

1) Кіріспе бөлім (10 минут)

Форматы: ЖИ-чаты және визуализациялар қолданылған интерактивті түсіндіру

Сабақтың алғашқы кезеңінде мұғалім оқушылардың бастапқы білімін белсендіру мақсатында қысқаша проблемалық сұрақтар қояды: «Интернетте ашылған сайт неге бірнеше секунд ішінде жүктеледі?»

«Деректер бір құрылғыдан екіншісіне қандай жолмен жетеді?»

Одан кейін мұғалім OSI моделі мен TCP/IP архитектурасына шолу жасап, негізгі ұғымдарды (қабаттар қызметі, деректер пакеті, протокол ұғымы) визуалды материалдар арқылы түсіндіреді. Оқушылар түсінбеген тұстарын ЖИ-чатқа сұрақ қою арқылы нақтылап отырады.

ЖИ-боттың мүмкіндігі сабақ барысында мына бағытта қолданылады:

қиын ұғымдарды қарапайым мысалмен немесе ұқсастық арқылы түсіндіру;

терминдерге қысқа әрі дәл анықтама беру;

OSI қабаттарын сызба түрінде көрсету;

«TCP мен UDP айырмашылығы», «транспорттық қабат не үшін керек?» сияқты негізгі сұрақтарға толық жауап ұсыну.

Осылайша кіріспе бөлім оқушыларды тақырыпқа қызықтырып, келесі практикалық кезеңге дайындық қалыптастырады.

2) Практикум (20 минут)

Форматы: Виртуалды зертханада топтық жұмыс және ЖИ-ассистент қолдауы

Оқушылар 2–3 адамнан топтарға бөлініп, виртуалды зертхана ортасында тәжірибелік тапсырма орындайды (мысалы, желіні модельдеу және құрылғыларды баптау).

Тапсырма мазмұны: «Екі компьютер мен маршрутизатордан тұратын желіні құрастырыңыздар. IP-адрес беріп, TCP/IP арқылы деректер пакетін жіберуді баптаңыздар. Пакеттің OSI қабаттары бойынша өту ретін талдап көрсетіңіздер.»

Бұл кезеңде ЖИ-ассистент келесі функцияларды орындайды:

- оқушылардың әрекетін бақылап, қателерді жылдам анықтау;
- дұрыс емес параметр енгізілген жағдайда нақты түзету нұсқауын беру;
- пакеттің жүруін көрнекі түрде көрсету;
- орындалған жұмыс бойынша қысқаша есептеме (есеп беру) қалыптастыру.

Практикум барысында оқушылар желіні тек «құрастырып қана қоймай», сонымен бірге байланыс неге бұзылғанын немесе пакет неге өтпей қалғанын талдайды. Бұл оқушылардың желілік логикасын қалыптастыруға және техникалық ойлау дағдысын дамытуға ықпал етеді.

3) Бейімделмелі тест (15 минут)

Форматы: ЖИ тест платформасында жеке жұмыс

Оқушылар өз бетімен қысқаша бейімделмелі тест тапсырады. ЖИ жүйесі сұрақтарды оқушының жауаптарына қарай өзгертіп, әр білім алушыға сәйкес деңгейде ұсынады:

базалық деңгейде: OSI қабаттарын атау, қызметін анықтау;

орта деңгейде: TCP/IP құрамындағы протоколдарды сәйкестендіру;

жоғары деңгейде: нақты жағдайға талдау жасау (мысалы, «дерек жеткізілмей қалса, мәселе қай қабатта болуы мүмкін?»).

Тест соңында ЖИ әр оқушыға жеке кері байланыс береді:

- қате кеткен сұрақтарды көрсетеді;
- түсіндіру ұсынады;
- қай тақырыпқа қайта оралу керегін ұсынады.

Бұл кезең оқушылардың білім деңгейін нақты бағалауға және білімдегі олқылықтарды жедел анықтауға мүмкіндік береді.

4) Жобалық тапсырма (15 минут)

Форматы: ЖИ симуляторы арқылы кибершабуылды талдау (топтық жұмыс)

Сабақтың қорытынды бөлігінде оқушылар желі қауіпсіздігімен байланысты шағын жобалық тапсырма орындайды.

Тапсырма:

«DDoS шабуылының жұмыс механизмін талдаңыздар және серверді қорғау тәсілдерін ұсыныңыздар.»

ЖИ-симулятор арқылы оқушылар шабуыл қалай іске асатынын, трафиктің қалай көбейетінін, сервердің жауап беру уақытының төмендеуін тәжірибе жүзінде байқайды.

Оқушылар ұсынылатын қорғаныс тәсілдерін негіздейді:

- трафикті шектеу (rate limiting);
- фаервол ережелері;
- жүктемені теңестіру (load balancing);
- күмәнді сұраныстарды сүзгілеу.

Жобалық тапсырма оқушылардың желі теориясын өмірлік жағдаймен байланыстыруына және киберқауіпсіздік туралы базалық түсінігін қалыптастыруына ықпал етеді.

Қорытынды (рефлексия – 2–3 минут)

Сабақ соңында мұғалім оқушылардың пікірін жинақтау үшін қысқаша рефлексия ұйымдастырады:

«OSI қабаттарының ішінде ең маңыздысы қайсы және неге?»

«TCP мен UDP қай жағдайда тиімді?»

«Виртуалды зертхана сізге нені түсінуге көмектесті?»

Қорытынды

Жасанды интеллект технологияларын мектептегі информатика пәнінде, әсіресе «Компьютерлік желілер» тақырыбын оқытуда қолдану оқу үдерісін сапалық тұрғыдан жаңа деңгейге көтеруге мүмкіндік береді. Аталған тәсіл оқытуды жекелендіру, оқу мазмұнын көрнекі әрі түсінікті ұсыну, сондай-ақ білімді тәжірибе арқылы бекіту мүмкіндігін кеңейтіп, білім алушылардың теориялық материалды саналы түрде меңгеруіне ықпал етеді. Нәтижесінде оқушы ақпаратты жай ғана жаттап қоймай, желілік процестердің логикасын түсініп, оны практикалық тапсырмалар арқылы қолдануды үйренеді.

Сонымен қатар білім беруді дамытудың перспективалық бағыты дәстүрлі оқыту жүйесін толық алмастыру емес, керісінше технологиялық және педагогикалық мүмкіндіктерді үйлестіретін гибридті, адамға бағытталған білім беру моделін қалыптастыру болып табылады. Мұндай модельде жасанды интеллекттің аналитикалық және автоматтандыру әлеуеті мұғалімнің кәсіби шеберлігімен, әдістемелік құзыреттілігімен, эмпатиясымен және шығармашылық тәсілімен өзара сабақтасып, оқыту тиімділігін арттыра түседі. Осы тұрғыдан ЖИ педагогтің орнын басатын құрал ретінде емес, оқу процесін жетілдіретін және мұғалімнің кәсіби мүмкіндігін кеңейтетін серіктес ресурс ретінде қарастырылады.

Пайдаланылған әдебиеттер

1. Буцзак А.Л., Гювен Э. Кибершабуылдарды анықтауда интеллектуалды деректер талдауы мен машиналық оқыту әдістеріне шолу // Компьютерлік желілер және киберқауіпсіздік. 2016. №4. 56–78-б.

2. Финкельштейн Н.Д., Адамс У.К., Келлер К.Дж. және т.б. Виртуалды зертханалар: оқу процесінде нақты жабдықты алмастыру мүмкіндігі // Қазіргі білім беру технологиялары. 2005. №3. 45–60-б.

3. Форузан Б.А. Компьютерлік желілер және деректерді беру. 5-басылым. Мәскеу: Техносфера, 2014. 1120 б.

4. Гудзиал М. Баршаға арналған білім беру технологиялары: оқушылар қажеттілігін ескере отырып оқыту жобалау. Мәскеу: БИНОМ. Білім зертханасы, 2020. 345 б.

5. Лакин Р., Холмс У., Гриффитс М., Форсье Л.Б. Интеллектті босату: білім беруде ЖИ қолдануды қолдайтын дәлелдер. Мәскеу: Просвещение, 2017. 210 б.

6. Попеничи С.А., Керр С. Жасанды интеллекттің жоғары білімдегі оқыту мен үйретуге ықпалы // Педагогикалық ғылымдар. 2017. №5. 112–125-б.

A STUDY OF SERVICES AND INTERFACES FOR COLLABORATIVE DATA PROCESSING IN INTELLIGENT SENSOR NETWORKS

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ИССЛЕДОВАНИЕ СЕРВИСОВ И ИНТЕРФЕЙСОВ ДЛЯ СОВМЕСТНОЙ ОБРАБОТКИ ДАННЫХ В ИНТЕЛЛЕКТУАЛЬНЫХ СЕНСОРНЫХ СЕТЯХ

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Abstract

The exponential growth of Internet of Things (IoT) devices and the increasing complexity of information infrastructures are leading to increasing volumes of streaming data generated by intelligent sensor networks. The traditional cloud-based processing model, based on transmitting raw data to remote processing centers, exhibits low scalability, high latency, and significant energy consumption. This article examines approaches to building collaborative computing architectures in intelligent sensor networks based on fog and edge computing. We analyze service models and communication interfaces that ensure distributed intelligence, semantic data consistency, and system resilience under resource-constrained and unstable communication channels.

Аннотация

Экспоненциальный рост числа устройств Интернета вещей (IoT) и усложнение информационных инфраструктур приводят к увеличению объемов потоковых данных, генерируемых интеллектуальными сенсорными сетями. Традиционная облачно-ориентированная модель обработки, основанная на передаче «сырых» данных в удаленные центры обработки, демонстрирует низкую масштабируемость, высокие задержки и значительные энергетические затраты. В статье рассматриваются подходы к построению архитектур совместных вычислений в интеллектуальных сенсорных сетях на основе туманных и пограничных вычислений. Выполняется анализ сервисных моделей и коммуникационных интерфейсов, обеспечивающих распределенный интеллект, семантическую согласованность данных и устойчивость системы в условиях ограниченных ресурсов и нестабильных каналов связи.

Keywords: Intelligent Sensor Networks, Iot, Distributed Computing, Fog Computing, Edge Computing, MQTT, Coap, DDS, Collaborative Data Processing.

Ключевые слова: Интеллектуальные Сенсорные Сети, Iot, Распределенные Вычисления, Fog Computing, Edge Computing, MQTT, Coap, DDS, Совместная Обработка Данных.

Введение

На фоне повсеместного распространения Интернета вещей (IoT) и растущей сложности информационных инфраструктур все большее значение приобретает способность сетей эффективно использовать генерируемые данные. Современные сенсорные системы характеризуются высокой плотностью узлов, непрерывной генерацией потоковой информации и жесткими требованиями к оперативности принятия решений. Одним из ключевых узких мест таких распределенных систем остается канал передачи информации от сенсорных устройств к центрам обработки и принятия решений. Классическая облачно-ориентированная парадигма, предполагающая передачу полного массива «сырых» измерений

на удаленные серверы, демонстрирует ограниченную масштабируемость и становится неустойчивой в условиях экспоненциального роста числа конечных узлов. Рост сетевого трафика, увеличение задержек, зависимость от стабильности каналов связи и значительные энергетические затраты делают данный подход малопригодным для систем реального времени и критически важных приложений.

В ответ на указанные ограничения активно развиваются подходы совместной обработки данных, при которых вычислительная нагрузка переносится ближе к источникам информации - на уровень периферийных устройств, шлюзов и локальных вычислительных узлов. В результате пассивные поля датчиков трансформируются в интеллектуальные распределенные вычислительные кластеры, способные выполнять предварительный анализ, фильтрацию, агрегацию и контекстную интерпретацию данных до их передачи в вышестоящие уровни системы. Такой подход позволяет существенно снизить объем передаваемой информации и повысить устойчивость функционирования сети.

Интеллектуальные сенсорные сети (Intelligent Sensor Networks, ISN) становятся базовым компонентом систем промышленной автоматизации, мониторинга окружающей среды, «умных» городов и киберфизических систем. Их применение обеспечивает более точное и своевременное реагирование на изменения в контролируемой среде, а также повышает автономность и адаптивность систем управления. Однако эффективность ISN напрямую зависит от архитектуры взаимодействия узлов, используемых служб распределенной обработки и интерфейсов передачи данных, обеспечивающих согласованность, надежность и масштабируемость системы в условиях гетерогенной и динамически изменяющейся среды.

Проблемы традиционных архитектур сенсорных сетей

Традиционные архитектуры сенсорных сетей в большинстве случаев основаны на централизованной модели обработки данных, при которой все измерения, генерируемые периферийными узлами, передаются в единый центр обработки или облачную платформу. Такой подход был оправдан на ранних этапах развития сенсорных систем, когда число узлов было ограниченным, а требования к задержке и автономности - относительно низкими. Однако в условиях масштабных IoT-развертываний централизованная архитектура становится существенным ограничивающим фактором. Одной из ключевых проблем является перегрузка каналов связи при высокой плотности сенсорных узлов. Массовая передача «сырых» данных приводит к резкому росту сетевого трафика, увеличению числа коллизий и снижению пропускной способности сети. В беспроводных средах это особенно критично, поскольку радиочастотный спектр является ограниченным ресурсом, а его перегрузка напрямую влияет на стабильность передачи данных [1].

Еще одной существенной проблемой является рост задержек и джиттера, что недопустимо для систем реального времени. Потоковые данные с сенсоров имеют высокую временную чувствительность, и их ценность зачастую определяется моментом генерации. При централизованной обработке данные проходят несколько сетевых хопов, что приводит к непредсказуемым задержкам, особенно в условиях нестабильных каналов связи или высокой нагрузки на облачную инфраструктуру.

Централизованная архитектура также снижает отказоустойчивость системы. При потере связи с облачным центром или отказе центрального узла сенсорная сеть фактически теряет возможность выполнять аналитические и управляющие функции. Это делает такие системы уязвимыми для сетевых сбоев, атак типа отказа в обслуживании и аварийных ситуаций, что особенно критично для промышленных и киберфизических приложений. С точки зрения энергопотребления централизованная модель также оказывается неэффективной. Конечные сенсорные устройства, как правило, обладают жесткими ограничениями по емкости аккумуляторов и вычислительным ресурсам. Постоянная передача больших объемов данных значительно увеличивает энергозатраты, сокращая срок автономной работы узлов и повышая стоимость обслуживания сети. Классическая архитектура не позволяет выполнять контекстную интерпретацию данных на уровне источника. Сенсорные узлы действуют исключительно как устройства сбора информации, не обладая возможностью учитывать локальный контекст, коррелировать данные с соседними узлами или фильтровать незначимые события. В результате система оперирует большими объемами избыточной информации, что снижает общую эффективность анализа и принятия решений.

Таким образом, потоковые данные с сенсоров обладают ценностью преимущественно в момент их генерации, и любые задержки передачи или десинхронизация процессов могут привести к некорректным управленческим решениям, сбоям в автоматизированных системах и материальному ущербу. Эти ограничения обуславливают необходимость перехода от централизованных моделей к распределенным архитектурам совместной обработки данных [2].

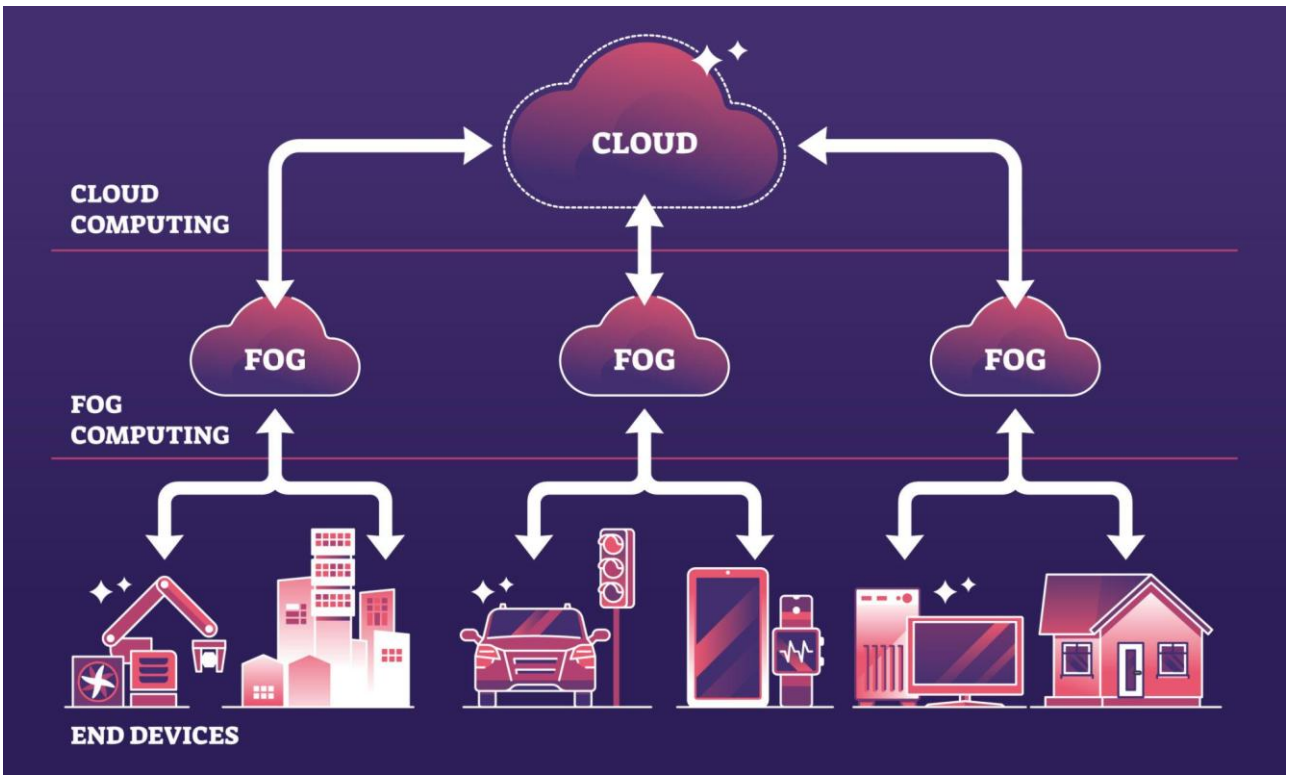

Рисунок 1. Сравнение централизованной архитектуры сенсорных сетей и распределенной модели с пограничной обработкой данных.

На рисунке показана иерархическая архитектура обработки данных в IoT, объединяющая три уровня вычислений:

Уровень конечных устройств - сенсоры, бытовые и промышленные устройства, транспорт и носимая электроника, которые генерируют первичные данные.

Уровень туманных вычислений - промежуточные узлы и шлюзы, расположенные ближе к источникам данных, выполняющие локальную обработку, фильтрацию и агрегацию информации.

Облачный уровень - централизованная инфраструктура для глубокой аналитики, хранения данных и глобального управления. Стрелки отражают двусторонний обмен данными между уровнями, демонстрируя снижение задержек и нагрузки на сеть за счет переноса части вычислений с облака на периферию.

Совместные вычисления и интерфейсы взаимодействия в интеллектуальных сенсорных сетях

Ключевым направлением повышения функциональности интеллектуальных сенсорных сетей является внедрение механизмов распределенного интеллекта, предполагающих перенос части вычислительных и аналитических функций с централизованных облачных платформ на периферийные уровни сети. Такой подход позволяет учитывать специфику потоковых данных, минимизировать задержки и повысить автономность функционирования системы. Архитектура распределенного интеллекта в ISN базируется на двух взаимодополняющих компонентах. Первый компонент представлен службами агрегации, фильтрации и локального анализа данных, реализуемыми непосредственно на сенсорных узлах, микроконтроллерах или пограничных шлюзах. Эти службы позволяют предварительно обрабатывать данные, устранять шум, выявлять аномалии и формировать обобщенные представления информации до ее передачи в вышестоящие уровни [3]. В результате существенно снижается объем передаваемого трафика, а вычислительные ресурсы облака используются только для задач высокого уровня абстракции. Второй компонент включает стандартизированные интерфейсы межмашинного взаимодействия, обеспечивающие обмен не только «сырыми» данными, но и знаниями, событиями и контекстной информацией. Такой обмен позволяет узлам сенсорной сети координировать свои действия, согласовывать интерпретацию измерений и принимать коллективные решения. В отличие от традиционных моделей, ориентированных на передачу байтовых потоков, данный подход формирует семантически насыщенную коммуникационную среду. Применение концепций пограничных и туманных вычислений позволяет выполнять анализ данных непосредственно в месте их возникновения или в непосредственной близости от него. Это особенно важно в условиях нестабильных каналов связи, когда связь с центральным сервером может быть прерывистой или иметь непредсказуемые задержки. Локальная

совместная обработка данных обеспечивает сохранение работоспособности системы даже при частичной изоляции сегментов сети.

Интерфейсы и протоколы взаимодействия узлов

Реализация распределенного интеллекта в ISN невозможна без эффективных и легковесных коммуникационных интерфейсов. В условиях жестких ограничений по вычислительным ресурсам, объему памяти и энергопотреблению использование тяжелых сетевых стеков является непрактичным. В связи с этим наибольшее распространение получили специализированные протоколы межмашинного взаимодействия, оптимизированные для IoT-среды.

Протокол CoAP (Constrained Application Protocol) ориентирован на устройства с минимальными ресурсами и использует модель взаимодействия, близкую к REST-подходу. Он обеспечивает низкие накладные расходы и подходит для сценариев, где важна простота реализации и энергоэффективность. Однако при высокой плотности событий CoAP может демонстрировать ограниченную масштабируемость. Протокол MQTT реализует асинхронную модель обмена сообщениями publish/subscribe, что делает его эффективным для событийно-ориентированных систем. Использование брокера позволяет разгрузить конечные узлы и обеспечить гибкую маршрутизацию сообщений. Благодаря низкому сетевому оверхеду MQTT широко применяется в распределенных сенсорных системах, где важны масштабируемость и устойчивость при нестабильных каналах связи [4]. Протокол DD ориентирован на системы реального времени с жесткими требованиями к задержке, надежности и детерминизму доставки данных. В отличие от MQTT и CoAP, DDS поддерживает прямое взаимодействие между узлами без обязательного центрального брокера, что делает его особенно привлекательным для критически важных киберфизических систем и промышленных приложений. Выбор конкретного интерфейса взаимодействия определяется требованиями прикладного сценария, включая допустимую задержку, уровень надежности доставки, масштабируемость и энергетическую эффективность. На практике все чаще используются гибридные архитектуры, в которых разные протоколы применяются на различных уровнях сенсорной сети.

Таблица 1. Сравнительная характеристика протоколов взаимодействия в ISN

Параметр	CoAP	MQTT	DDS
Тип взаимодействия	Request/Response	Publish/Subscribe	Data-Centric Pub/Sub
Требования к ресурсам	Очень низкие	Низкие	Средние
Задержка	Низкая	Низкая–средняя	Минимальная
Масштабируемость	Ограниченная	Высокая	Высокая
Поддержка реального времени	Ограниченная	Частичная	Полная
Типичные сценарии	Простые сенсоры	IoT-платформы	Киберфизические системы

Таким образом, совместные вычисления и распределенный интеллект в интеллектуальных сенсорных сетях формируют основу для создания масштабируемых, энергоэффективных и отказоустойчивых систем. Использование легковесных интерфейсов взаимодействия в сочетании с edge- и fog-вычислениями позволяет перейти от передачи «сырых» данных к обмену знаниями и событиями, что существенно расширяет функциональные возможности ISN.

Архитектура сервисов и оркестрация ресурсов в интеллектуальных сенсорных сетях

Современные интеллектуальные сенсорные сети функционируют в условиях выраженной гетерогенности среды, объединяя вычислительно мощные пограничные шлюзы, встраиваемые системы и энергозависимые микроконтроллеры с различными операционными системами, аппаратными платформами и стандартами связи. Такая неоднородность усложняет проектирование архитектуры и требует использования сервисно-ориентированного подхода, обеспечивающего масштабируемость, гибкость и устойчивость системы в целом.

Одним из базовых архитектурных требований является поддержка динамической топологии сети и мобильности узлов. В реальных сценариях эксплуатации ISN узлы могут временно отключаться, перемещаться или изменять параметры связи в зависимости от внешних условий. В этих условиях статические конфигурации становятся неэффективными, а система должна обладать способностью автоматически адаптироваться к изменениям топологии без вмешательства оператора. Важнейшую роль в таких архитектурах играет механизм автоматического обнаружения сервисов. Он позволяет узлам динамически находить доступные вычислительные и аналитические сервисы, определять их характеристики и устанавливать взаимодействие без предварительной конфигурации. Это особенно актуально для распределенных сред с большим количеством автономных устройств, где ручное управление становится невозможным [5].

Еще одной критической задачей является обеспечение семантической совместимости данных. В условиях гетерогенных сенсорных источников даже формально корректно переданные данные могут

быть интерпретированы неверно из-за различий в форматах, единицах измерения или контексте. Использование унифицированных моделей данных, онтологий и метаданных позволяет узлам корректно интерпретировать информацию, объединять данные из различных источников и формировать согласованную картину наблюдаемой среды. С точки зрения надежности архитектура ISN должна обеспечивать самовосстановление и адаптацию к отказам. Отказ отдельных узлов, каналов связи или сервисов не должен приводить к деградации всей системы. Для этого применяются механизмы репликации сервисов, перераспределения нагрузки и локального принятия решений. Такой подход позволяет сохранять работоспособность системы даже при частичной деградации инфраструктуры. Особое внимание в распределенных архитектурах уделяется информационной безопасности. Децентрализованная обработка данных расширяет поверхность атаки и создает новые угрозы, включая внедрение вредоносных узлов, искажение результатов коллективной обработки и подмену сервисов. В связи с этим архитектура сервисов должна включать механизмы аутентификации, доверия между узлами и контроля целостности данных, не создавая при этом чрезмерной нагрузки на ограниченные ресурсы конечных устройств.

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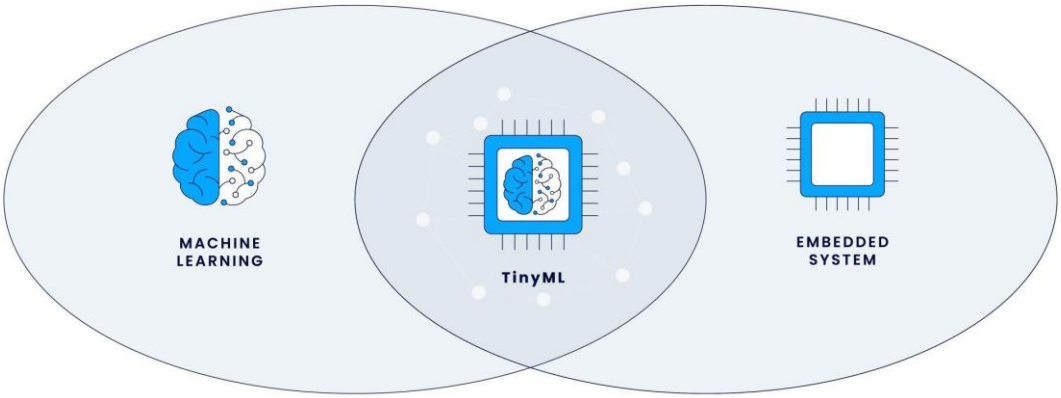

Рисунок 2. Оркестрация вычислений и федеративное обучение моделей в интеллектуальных сенсорных сетях

Архитектура сервисов и механизмов оркестрации ресурсов является критически важным элементом интеллектуальных сенсорных сетей. Использование сервисно-ориентированного подхода, динамического обнаружения сервисов и распределенной оркестрации вычислений позволяет эффективно функционировать ISN в условиях гетерогенной, динамичной и ресурсно-ограниченной среды, а также создает основу для внедрения интеллектуальных алгоритмов на периферии сети.

Оценка эффективности предлагаемых подходов

Применение распределенных сервисов и механизмов совместной обработки данных в интеллектуальных сенсорных сетях оказывает комплексное влияние на ключевые показатели производительности системы. В отличие от традиционных централизованных архитектур, предлагаемые подходы ориентированы на локальную обработку информации и обмен агрегированными результатами, что позволяет более рационально использовать сетевые и вычислительные ресурсы [7].

Одним из наиболее значимых эффектов является снижение объема передаваемого сетевого трафика. Предварительная фильтрация, агрегация и выявление значимых событий на периферийных узлах позволяют исключить передачу избыточных или неинформативных данных. В результате нагрузка на каналы связи существенно уменьшается, что особенно важно для беспроводных и маломощных сетей с ограниченной пропускной способностью. Распределенная обработка также способствует уменьшению среднего времени отклика системы. Перенос аналитических функций ближе к источнику данных позволяет сократить количество сетевых переходов и минимизировать задержки, связанные с удаленной обработкой. Это критически важно для приложений реального времени, включая системы промышленного управления, мониторинга аварийных состояний и киберфизические системы. С точки зрения энергопотребления предложенные подходы демонстрируют повышение энергоэффективности конечных устройств. Сокращение объема передаваемых данных и уменьшение времени активной работы радиомодулей приводит к снижению энергозатрат, что увеличивает срок автономной работы сенсорных узлов и снижает эксплуатационные расходы. Еще одним важным результатом является повышение отказоустойчивости интеллектуальных сенсорных сетей. Локальная совместная обработка данных позволяет системе продолжать функционирование даже при временной потере связи с центральным узлом или облачной платформой. Узлы способны принимать решения на основе локального контекста и взаимодействия с ближайшими соседями, что снижает зависимость от централизованных компонентов.

Наконец, распределенные архитектуры обеспечивают масштабируемость системы при росте числа узлов. По мере увеличения плотности сенсорных устройств вычислительная нагрузка распределяется между элементами сети, предотвращая перегрузку центральных узлов и каналов связи. Это позволяет адаптировать ISN к расширению инфраструктуры без радикального изменения архитектуры.

Таблица 2. Сравнение показателей эффективности архитектур ISN

Показатель	Централизованная обработка	Распределенные сервисы
Объем передаваемых данных	Высокий	Сниженный
Среднее время отклика	Высокое	Минимальное
Энергопотребление узлов	Повышенное	Оптимизированное
Отказоустойчивость	Низкая	Высокая
Масштабируемость	Ограниченная	Высокая

Переход от передачи «сырых» данных к обмену агрегированной и контекстно-зависимой информацией позволяет существенно повысить потенциал интеллектуальных сенсорных сетей. Использова-

ние распределенных сервисов и совместной обработки данных обеспечивает снижение задержек, повышение энергоэффективности, устойчивость к отказам и масштабируемость, что делает данные подходы перспективными для широкого спектра IoT-приложений.

Заключение

В данной статье проведен комплексный анализ архитектурных принципов построения служб и интерфейсов, обеспечивающих поддержку совместных вычислений в интеллектуальных сенсорных сетях. Показано, что традиционные централизованные модели обработки данных, основанные на передаче полного объема измерений в удаленные центры обработки, не соответствуют современным требованиям IoT-систем по задержке, надежности, энергоэффективности и масштабируемости. Экспоненциальный рост числа сенсорных узлов и увеличение плотности трафика делают такие архитектуры уязвимыми к перегрузкам и сбоям связи.

В ходе исследования обоснована целесообразность перехода к распределенным архитектурам, использующим механизмы совместной обработки данных и распределенного интеллекта. Применение пограничных и туманных вычислений позволяет выполнять аналитические операции непосредственно в месте возникновения данных, снижая нагрузку на каналы связи и обеспечивая устойчивость системы в условиях нестабильной сетевой инфраструктуры. Особое внимание уделено роли сервисно-ориентированных архитектур, которые обеспечивают гибкость, адаптивность и возможность динамической оркестрации вычислительных ресурсов.

В статье выполнен сравнительный анализ легковесных интерфейсов межмашинного взаимодействия, таких как CoAP, MQTT и DDS, и показано, что выбор протоколов должен осуществляться с учетом требований конкретного прикладного сценария, включая допустимые задержки, уровень надежности и ограничения ресурсов конечных устройств. Подчеркнута важность перехода от передачи «сырых» данных к обмену агрегированной, контекстно-зависимой и семантически согласованной информацией, что существенно повышает эффективность коллективного анализа.

Рассмотренные архитектурные решения демонстрируют положительное влияние на ключевые показатели функционирования интеллектуальных сенсорных сетей, включая снижение объема сетевого трафика, уменьшение времени отклика, повышение энергоэффективности и отказоустойчивости, а также обеспечение масштабируемости при росте числа узлов. Кроме того, показано, что внедрение распределенного интеллекта создает основу для интеграции методов машинного обучения на периферии сети, включая подходы федеративного обучения и технологии TinyML. Полученные результаты формируют теоретическую основу для дальнейшего развития интеллектуальных сенсорных сетей и автономных киберфизических систем. Перспективными направлениями будущих исследований являются разработка унифицированных онтологий данных, совершенствование механизмов доверия и безопасности в распределенных средах, а также формализация моделей динамической оркестрации сервисов с учетом ограничений ресурсов и требований реального времени. Использование распределенных сервисов и специализированных интерфейсов взаимодействия является научно-техническим приоритетом и ключевым фактором повышения эффективности и надежности IoT-инфраструктур нового поколения.

Список литературы

1. Akyildiz, I. F., & Vuran, M. C. Wireless Sensor Networks. John Wiley & Sons, 2010.
2. Atzori, L., Iera, A., & Morabito, G. The Internet of Things: A survey. Computer Networks, 54(15), 2010, 2787–2805.
3. Shelby, Z., Hartke, K., & Bormann, C. The Constrained Application Protocol (CoAP). IETF RFC 7252, 2014.
4. Banks, A., & Gupta, R. MQTT Version 3.1.1. OASIS Standard, 2014.
5. Bonomi, F., et al. Fog Computing and Its Role in the Internet of Things. ACM, 2012.
6. Perera, C., et al. Context Aware Computing for the Internet of Things. IEEE, 2014.
7. Hussain, S., & Hussain, F. K. Federated learning in IoT. FGCS, 2018.

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ISBN
9 789244 514887